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2.7 GHZ polarization and flux density measurements of variable radio sources.

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2.7 GHZ POLARIZATION AND FLUX DENSITY MEASUREMENTS OF VARIABLE RADIO SOURCES

A Dissertation Presented

By

JOHN EDWARD KAPITZKY

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ABSTRACT

2.7 GHz Polarization and Flux Density Measurements
of Variable Radio Sources
(January 1976)

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Several studies have shown the existence of variations in the flux densities and polarization properties of some extragalactic radio sources with timescales ranging from years to days. The nature of the expanding source model, often employed in understanding these radio sources' variations, suggested certain advantages in monitoring the flux densities and polarization properties of these objects at relatively long wavelengths. In accordance, observations were made of many extragalactic radio sources at 11 cm on the NRAO 300 foot radio telescope in Green Bank, West Virginia for roughly six consecutive days every three to four months. Each observed source drifted through the beam patterns of three azimuthally-aligned, linearly polarized feeds once a day. The radiometer attached to one of the feeds was in a conventional load-switching configuration. Each of the other two feeds was connected to a radiometer whose input was switched between two ortho-

gonal dipoles contained within the feed (called polarization-switching). The orientations of the dipole pairs within the three feeds and the combination of load-switching and polarization-switching theoretically allowed determination of total flux, degree of polarization, and polarization position angle for each observed radio source. After calibration of the telescope system and removal of instrumental polarization, this goal was achieved. The results at 11 cm were then combined with flux density observations at 1.9 and 3.8 cm made at the Haystack Radio Observatory and with flux observations at 9.6 mm made with the NRAO 36 foot Kitt Peak radio telescope. The 1.9 cm and 3.8 cm observations were made in a program initiated by Prof. W. A. Dent and later supported by the author. The 9.6 mm observations were supplied by Professors W. A. Dent and R. W. Hobbs.

The multi-wavelength monitoring revealed that radio outbursts in some of the sources were interpretable in terms of the expanding source model and its extensions. The 11 cm observations were especially valuable, because many of the outbursts transparent to radio radiation at shorter wavelengths displayed the time delays and reduced flux density amplitudes at 11 cm that are associated with large opacities and changes in opacity in the expanding source model. Behavior in 3C120 and 3C454.3 suggested that dispersion through an intergalactic medium contributes little to the measured delays in the times of occurrence of a given outburst at several frequencies.

A large number of sources showed little variation in 11 cm polarization. But the large changes in position angle for a few of the objects suggests a high degree of order in magnetic field orientations within some sources. Most of the well-defined changes in position angle support predictions by Aller about how polarization should vary within an expanding source and further support the idea that the larger opacities encountered at longer wavelengths aid in clarifying behavior in the expanding source model. A few objects have shown polarization variations while remaining constant in flux density.

The secondary objective of searching for signs of day to day variability in flux density in radio sources previously suspected of such activity has turned up negative results. A few new potential 11 cm variable radio sources have been found.

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CHAPTER I

INTRODUCTION

A. Objectives

The studies summarized in Tables I-1 and I-2 in this chapter show or suggest the existence of variations in the flux densities and the polarization properties of some extragalactic radio sources with timescales ranging from years to days. This study undertakes the systematic monitoring of flux density and polarization properties of a number of extragalactic objects at 11.1 cm, a wavelength longer than is usually employed in such investigations. This program's results will be combined with data taken at the Haystack Observatory at 1.9 and 3.8 cm and with results from the NRAO 36 foot antenna by Dent and Hobbs at 9 mm to provide material essential for the study of the evolution of extragalactic objects, including quasistellar objects.

The observations will then be tested for conformity with several predictions of the expanding source model. Because of the relatively long wavelength of observation (11.1 cm), opacity effects within the sources should be more important than at higher frequencies. This could manifest itself in measurable delays between the times of occurrence of an event at 3.8 cm and 11.1 cm, as well as in better-defined 90 degree changes in the polarization position angle (at 11.1 cm). Both of these predictions, as well as other qualitative features of the model, will be investigated. Furthermore, evidence of new variables will be sought and a search made for signs of day to day variability in the flux densities of some of the objects.

B. Background

A variety of astronomical objects emit electromagnetic radiation in the radio portion of the spectrum. The list includes planets, stars, supernova remnants, clouds of interstellar gas, galaxies, and quasistellar objects (QSO's). The extragalactic radio sources are especially interesting, since they can potentially reveal something about the processes and conditions existing during earlier epochs in the history of the Universe.

Although a few strong radio sources had been identified with galaxies through similarity of positions in the late 1940's, it was not until the early 1960's that most of the strongest radio sources had been associated with optical "radio galaxies" and star-like objects emitting radio waves. When the emission lines in the optical spectra of these supposed radio stars were interpreted as being highly redshifted spectral features of common elements, their distances were increased from parsecs to megaparsecs, and their energies emitted at radio wavelengths increased with the square of the new distances. In comparison with normal galaxies whose absolute radio luminosities were $\sim 10^{37}$ ergs/sec, some QSO's have radio luminosities of 10^{45} ergs/sec.

The discovery in 1965 of variations in the radio emission from some of these extragalactic objects was exciting. For not only did it raise new questions about the energy production mechanism (how does an object possibly only a few parsecs in size radiate more energy than an entire galaxy?), but it also opened up a new avenue of inquiry into the nature of the energy emission mechanism. It became important to identify extragalactic variable radio sources and to begin to measure the changes in their flux densities over a wide range of wavelengths.

The principal means of identifying potential variable sources has been examination of their radio spectra. At radio frequencies, graphs of the emission from radio sources versus wavelength appear as smooth lines with positive, negative, or no curvature, or as curves that are a combination of all three types. The spectral index, α, is defined by the relation

$$\log (S) = \alpha \log (\nu) + C$$

where S is the flux density
ν is the frequency
C is a constant

For a spectrum with no curvature, α is just the slope of the line in the log (S) - log (ν) plot. For more complex spectra, it can be defined as the tangent to the curve at a given frequency. While radio sources exist with a range of spectral shapes and indices, for most variable radio sources the spectral index is greater than -.5 or else the spectrum is complex in the wavelength region of variability.

The next section examines previous observations of variability. Then Chapter II reviews the expanding source model, which is usually employed to account for the variability in many extragalactic radio sources. Chapter III describes the observational portion of this study, and Chapter IV discusses the results. Chapter V presents the conclusions.

C. Previous Flux Density and Polarization Variability Observations

In the last decade several studies involving searches for large timescale (greater than several weeks) and short timescale (day to day) flux density variations in radio sources have been conducted. Also, in the past five years, several papers have been published recording time variations in the polarization properties. These studies have been summarized in Tables I-1 and I-2.

The bulk of sources that show large timescale variations can be crudely divided into several groups. Some sources (3C120, 3C273, 3C454.3) show multiple outburst behavior with timescales for the events of a few months. The outbursts overlap in many cases, making definition of base levels of constant flux density difficult to determine. Other sources (OJ287, BL Lac) exhibit rapid, multiple outbursts with shorter timescales (a month or less). For these objects the problem of resolving the outbursts is worse. Frequent observations are especially necessary and important for these sources. Another group of objects (2145+06) shows relatively monotonic behavior, either gradually increasing or decreasing in flux density. Superimposed on the monotonic emission from some of these objects are low level outbursts. Finally, there are a number of sources that have broad (1 year or more) convex or concave flux density-time curves, some with outbursts superimposed.

Most of the long term monitoring programs (see Table I-1) have been at wavelengths shorter than 6 cm, principally because the variability is a short wavelength phenomenon. Flux density outbursts are generally stronger at shorter wavelengths (shorter than ~6 cm). With a few possible exceptions at low frequencies (e.g., 408 MHz; Hunstead, 1972), the amplitude of variations decreases to very low levels for wavelengths longer than 6 cm. Nevertheless, observations at longer wavelengths are useful, for it is in this spectral region that opacity effects in the expanding source model should produce marked time delays in the events (compared with the times of occurrence at 2 cm and shorter wavelengths).

The above class of flux variations dealt with timescales of months up to years. But measurements of 3C273 (Pauliny-Toth and Kellerman, 1966), and BL Lac (Andrew et

Table I-1

Long Term Variations (Flux Density Only)

λ	Dates	Number of Objects	Location/Reference
9.5 mm	1970.7 - 1972.5	21	NRAO-Kitt Peak Dent and Hobbs, 1973
1.9 cm	1969.0 - 1973.0	32	Haystack Observatory Dent et al., 1974
2.7 cm	1970.5 - 1971.6	18	Univ. of Michigan Stull, 1972
2.8 cm	1966.6 - 1971.5	84	Algonquin Radio Obs. Medd et al., 1972
3.8 cm	1969.0 - 1971.6	22	Haystack Observatory Dent and Kojoian, 1972
4.5 cm	1967.7 - 1971.5	84	Algonquin Radio Obs. Medd et al., 1972
22 cm 40 cm }	1962.8 - 1966.1	78	NRAO-Green Bank 300' Pauliny-Toth and Kellerman, 1966
73 cm	1966.3 - 1972.0	4	Molonglo Hunstead, 1972

Table I-2

Short Term Variations

λ	Dates	Number of Objects	Location/Reference
2.8 cm } 4.5 cm	1968 - 1969	1	Algonquin Radio Obs. Andrew et al., 1969
11.1 cm	1969	37	CSIRO Wills, 1971
2.8 cm } 4.5 cm	1971	1	Algonquin Radio Obs. Andrew et al., 1971
2.8 cm 3.8 cm } 4.5 cm	1968 - 1970	1	Algonquin Radio Obs. MacLeod et al., 1971
2.8 cm	1971	19	Algonquin Radio Obs. Harvey et al., 1972
2.8 cm	1972	1	Algonquin Radio Obs. Andrew et al., 1974

Polarization Time Variations

λ	Dates	Number of Objects	Location/Reference
3.8 cm	1963.0 - 1967.0	3	Univ. of Michigan Aller and Haddock 1967
2.1 cm	1965.9 - 1967.6	7	NRAO-Green Bank 140' Hobbs et al., 1968
3.8 cm	1966.5 - 1968.3	40	Univ. of Michigan Aller, 1970a
2.8 cm } 4.5 cm	1968.4 - 1970.8	44	Algonquin Radio Obs. Bignell and Seaquist 1973
6.0 cm	1971.5 - 1973.7	15	Owens Valley Obs. Seielstad and Berge 1975

al., 1969) suggested timescales of a few weeks or less, prompting further investigation of this type of source. Wills (1971) and the Algonquin group (Harvey et al., 1972) conducted searches for short term variability in a variety of sources known to be variable with longer timescales. Wills at CSIRO measured flux densities at 11 cm of 37 sources, about half of which were known to be radio variables. From observations of two to nine days, day to day variations of 2 to 4 per cent were detected in four of the objects: 0106+01, CTA26, 0440-00, and 1510-08. No hourly variations were found in any of the sources. On the other hand, a search for short term time variations at Algonquin (2.8 cm) by Harvey et al. turned up negative results. They examined 19 sources, including three of Wills' four variables, for a 20 day period in late 1971. They found that only OJ287 and BL Lac showed any convincing evidence of daily variation. Harvey et al. suggested that such behavior is intermittent and that rapid variables may be quiescent for long periods. In any case, the task of establishing daily variations is a difficult one, considering that the level of variability as determined by Wills (2 to 4 per cent) is only slightly above the error levels of most flux density measurements.

The first evidence of time variations in polarization was found in 1967 when Aller and Haddock (1967) published observations of polarization covering 4 years in three sources: 3C279, 3C273, and 3C345. With degrees of polarization ranging from 2 to 4 per cent and time variations of 1 to 2 per cent of the total flux, the measurements represented a new source of information on the nature of extragalactic radio sources. These and additional early observations by Hobbs et al. (1968) of seven objects suggested the usefulness of full scale monitoring programs of many sources. The first such program, by Aller (1970a) at 3.8 cm, was begun in mid 1966. Other searches for polarization variations followed at 2.8 and 4.5 cm (Bignell and Seaquist, 1973), 6 cm (Seielstad and Berge, 1975), and 11 cm (Altschuler, 1974).

CHAPTER II

THEORY

After the discovery of variability in extra-galactic radio sources (Dent, 1965), several papers were written describing models that could explain the variations in flux density and polarization. Papers by van der Laan (1966), Pauliny-Toth and Kellerman (1966), and Kellerman and Pauliny-Toth (1967) developed a model in which a cloud of relativistic electrons expanded adiabatically after being injected into a region containing a homogeneous magnetic field of random orientation, resulting in the emission of synchrotron radiation that varied with time. The polarization properties of this model have been examined by Aller (1970b), Takarada (1970), and Pacholczyk and Swihart (1967, 1970, 1971, 1973, 1974). The result of all of these papers has been a model detailed enough for comparison with the data available on time variations. A summary of the expanding source model based on the work of van der Laan, Aller, and Takarada follows.

In its most basic form, the model begins with an injection (of unknown origin) of a uniform, spherical cloud of relativistic electrons into a volume containing a homogeneous magnetic field of strength B. Assuming the electrons have an isotropic velocity distribution and a number distribution N(E) of the form

$$N(E)dE = K(t)E^{-\gamma}dE \qquad \text{(II-1)}$$

where the energy E is confined to an interval $E \leq E \leq E_2$, then the frequency dependence of the volume emissivity (ε) and absorption (κ) coefficients due to the synchrotron radiation from the particles can be written

$$\varepsilon(\nu) \propto K(t)B^{\frac{\gamma + 1}{2}} \nu^{-(\gamma - 1)/2} \qquad \text{(II-2)}$$

$$\kappa(\nu) \propto K(t)B^{\frac{\gamma + 2}{2}} \nu^{-(\gamma + 4)/2} \qquad \text{(II-3)}$$

Note that K in equation II-1 is time dependent. The combination of emission and absorption from the cloud of electrons leads to two expressions for the observed flux density when II-2 and II-3 are substituted into II-4.

$$S(\nu) \propto \frac{\varepsilon}{\kappa}[1 - e^{-\kappa \ell}] \qquad \text{(II-4)}$$

One equation describes the emission at some time in the spectral region where the source is transparent to radiation. This occurs at frequencies above some frequency ν_m, ν_m being the frequency at which flux density is maximum at that time. The other expression describes the emission in the spectral region where the source is opaque, which occurs for $\nu << \nu_m$. If $S(\nu)$ is the observed flux density and θ is the angular size of the source at the time then

$$S(\nu) \propto B^{-1/2} \theta^2 \nu^{2.5}, \; \nu<<\nu_m \qquad \text{(II-5)}$$

$$S(\nu) \propto K(t)B^{(\gamma + 1)/2}\ \theta^3\ \nu^{-(\gamma - 1)/2},$$

$$\nu >> \nu_m \qquad \text{(II-6)}$$

If magnetic flux is conserved, if the electron gas expands adiabatically, and if particles neither enter nor escape from the region, then

$$B \propto r^{-2} \qquad \text{(II-7a)}$$

$$\theta \propto r \qquad \text{(II-7b)}$$

$$K \propto r^{-2-\gamma} \qquad \text{(II-7c)}$$

where r is the radius of the source. When equations II-5, II-6, and II-7 are combined with the parameter ρ (the relative radius, defined as $\rho = r/r_o$ where r, r_o are the radii of the source at times t and t_o, respectively), then the flux densities in the transparent and opaque parts of the radio spectrum become

$$S(\nu,\rho) = S_o(\nu)\rho^3,\ \nu << \nu_m \qquad \text{(II-8)}$$

$$S(\nu,\rho) = S_o(\nu)\rho^{-2\gamma},\ \nu >> \nu_m \qquad \text{(II-9)}$$

where $S_o(\nu)$ is the flux density at time t_o. It can also be shown that

$$\nu_m(\rho)/\nu_m(\rho_o) = \rho^{-(4\gamma + 6)/(\gamma + 4)} \qquad \text{(II-10)}$$

(where ν_m is the frequency of maximum flux density when the relative radius is ρ) and

$$S_m(\rho)/S_m(\rho_o) = \rho^{-(7\gamma + 3)/(\gamma + 4)} \qquad \text{(II-11)}$$

(where $S_m(\rho)$ is the maximum flux density when the relative radius is ρ) and

$$S_m(\nu_{m2})/S_m(\nu_{m1}) = (\nu_{m2}/\nu_{m1})^{(7\gamma + 3)/(4\gamma + 6)} \tag{II-12}$$

(where $S_m(\nu_{mi})$ is the maximum flux density during the outburst at frequency ν_{mi}).

From these equations it can be seen that the spectrum drops to lower flux densities and longer wavelengths as time goes on. Furthermore, what one would see at a fixed frequency is an increase in flux density as the cloud of electrons expands and the solid angle increases, producing a drop in the opacity, followed by a decrease in flux as a result of adiabatic energy losses of the relativistic particles and decreased magnetic field strength. The same behavior is observed at longer wavelengths, although the amplitude of the outburst is less (II-12) and the maximum occurs at a later time (II-10).

If the source expands with constant velocity, then $r \propto t$. Thus, since $\rho \propto r$,

$$S(\nu,t) = \begin{cases} S(\nu,t_1)(t/t_1)^3, & \nu << \nu_m \\ S(\nu,t_1)(t/t_1)^{-2\gamma}, & \nu >> \nu_m \end{cases} \tag{II-13}$$

At any frequency then, the flux density would increase more rapidly than it would decrease (if $\gamma > o$).

To discuss the polarization properties of the model, it is necessary to examine the emissivity and absorption coefficients, ε and κ, in the two planes of polarization, parallel and perpendicular to the magnetic field B. The ratios of these quantities in the two planes are

$$\varepsilon_{\perp}/\varepsilon_{\parallel} = (3\gamma + 5)/2 \qquad \text{(II-14)}$$

$$\kappa_{\perp}/\kappa_{\parallel} = (3\gamma + 8)/2 \qquad \text{(II-15)}$$

Then,

$$I_{\parallel} = (\varepsilon_{\parallel}/\kappa_{\parallel})[1 - \exp(-\tau_{\parallel})] \qquad \text{(II-16)}$$

$$I_{\perp} = (\varepsilon_{\perp}/\kappa_{\perp})[1 - \exp(-\tau_{\perp})] \qquad \text{(II-17)}$$

where $\tau_{\parallel} \propto \int\kappa_{\parallel}\, d\ell$, $\tau_{\perp} \propto \int\kappa_{\perp} d\ell$, and $I_{\parallel}$, $I_{\perp}$ refer to the emitted intensities in the two planes of polarization. If a coordinate system is chosen such that the Stokes parameter U is zero (also, V is zero in the isotropic case), then

$$Q = I_{\perp} - I_{\parallel} \qquad \text{(II-18)}$$

$$P \equiv |Q/I| = |I_{\perp} - I_{\parallel}|/(I_{\perp} + I_{\parallel}) \qquad \text{(II-19)}$$

where P is the degree of polarization. From II-14 through II-19 it can be shown that, for a uniform B field through the source,

$$P = (3\gamma + 3)/(3\gamma + 7) \text{ and } \chi \perp \vec{B},\ \tau << 1 \qquad \text{(II-20)}$$

$$P = 3/(6\gamma + 13) \text{ and } \chi \parallel \vec{B},\ \tau >> 1 \qquad \text{(II-21)}$$

where χ is the position angle of the polarized radiation. Notice that the position angle changes by 90 degrees from the time when $\tau >> 1$ to the later time during expansion when

$\tau << 1$. Aller pointed out that this shift occurs around the time when total flux from the outburst is at its maximum value.

For typical values of γ, ranging from 1 to 2, the above formulae indicate that degrees of polarization from 60% (optically thin region) to 15% (optically thick region) should be expected. That these high levels of polarization are not usually found, as is found by this and other studies (Aller, 1970a;Bignell, 1973; Wardle and Kronberg, 1974; Conway et al., 1974) points toward a level of complexity in the emission mechanism not found in this simple model. Putting aside the minor corrections that would be introduced by considering different values of γ, there still remain several more important effects that can influence the polarization in the expanding source model.

For example, the observed lower degree of polarization can be explained by changes in the magnetic field orientation through the source or by Faraday depolarization at longer wavelengths. In the latter, differential Faraday rotation, proportional to the square of the wavelength, results in a reduction in the net polarization as wavelength increases. Conway et al. (1974) found the depolarization in 46 out of 120 QSS's to be consistent with the Faraday effect due to thermal electrons within the source (electron densities of 3×10^{-6} to 3×10^{-3} cm^{-3} and B 10^{-4} to 10^{-5} gauss). However, Wardle and Kronberg (1974) have shown that this process does not have to dominate in all cases, since some of their measured sources have a larger degree of polarization at longer wavelengths.

Aller (1970b) has pointed out that changes with time in the observed polarization can arise without major alterations in the distribution of relativistic particles or in the structure of the magnetic field. If the depth to which the source is transparent should change, then the region from which the bulk of polarized flux comes may change. Consequently, if the magnetic field varies with position in the source, a change in the depth of transparency could produce a change in the observed polarization.

More complicated time variations in polarization can occur if multiple simple expanding sources should exist within one object. If several outbursts were to overlap in time, the net polarized flux from the whole object could be greater or smaller than that expected from the algebraic sum of the sources present. This, of course, would depend on the spacing of the outbursts in time, expansion velocities of the components, orientation and strength of the magnetic fields, etc. With so many parameters, model fitting becomes difficult.

Even neglecting complications concerning polarization variations, van der Laan's model is probably simpler than the actual situation in many sources. Kellerman and Pauliny-Toth (1967) noted that the 1966 change in flux density for 3C279 could be explained in terms of a density increase in relativistic particles toward the center of the cloud. Thus, the outer region could become optically thin while the inner region was still opaque. Such a density distribution would be reasonable if particle injection occurred over a period of time.

Along the same lines, Peterson and Dent (1973) examined several models for prolonged injection of electrons and came to the conclusion that models of this type are consistent with some observations. Specifically, fitting a prolonged injection model to observations of the 1966-1967 radio outburst in 3C273, Peterson and Dent were able to account for the observed amplitudes at 31 GHz and 88 GHz which were an order of magnitude smaller than the prediction of the simple model.

CHAPTER III

OBSERVATIONS

A. Introduction

As part of an overall goal to observe a variety of radio sources at a wide range of wavelengths, an observing program was begun in August 1972 on the 300 foot transit radio telescope of the National Radio Astronomy Observatory in Green Bank, West Virginia. The observations, made with a 3 feed (linearly polarized) 11 cm front end box, were intended to provide flux density and linear polarization data on selected radio sources. Runs of several consecutive 24 hour days of observation spaced at 3 to 4 month intervals were used to obtain data on flux density and polarization variations with timescales of several months and on daily flux variations.

Since the 300 foot telescope is a transit instrument, it is impossible to track sources for more than a few minutes. Thus, the usual technique of following a source while making polarization measurements was unusable. Instead, a method compatible with sources drifting through the antenna beam pattern from east to west had to be employed. A method was developed that would also make use of special properties of the 11 cm front end box.

The 11 cm box consisted of 4 parametric amplifier radiometers, each centered at 2695 MHz with 140 MHz bandwidths and system noise temperatures of approximately 120 degrees Kelvin (see Table III-1 for details). The 4 paramps were fed by 3 linearly polarized feeds aligned in right ascension, with the centered feed (channels 1 and 2) providing 2 of the paramps with signals polarized in the north-south and east-west planes. The east (channel 4) feed accepted polarized signals with a position angle of 45 degrees and the west (channel 3) feed signals with position angle 135 degrees.

A feature of the 11 cm system was that each feed had two orthogonal dipoles between which the receiver could be switched. The more conventional load-switching capability was also available in each feed. Both functions were used for these observations. The combination of channel 4 in load-switching and channels 1, 2, and 3 in polarization-switching allowed determination of the total flux S and Stokes parameters Q' and U' (the usual Stokes parameters normalized by the total flux) with the reduction procedure described below.

As a source drifted from east to west through the three azimuthally-aligned beams, each channel's radiometer output was a series of antenna temperatures (integration time: 2 seconds) characteristic of the convolution of the beam shape with the source brightness distribution. For point sources the responses were approximately Gaussian with beamwidths of around 5 minutes of arc. A least-squares fit of the data from each channel to Gaussians

Table III-1

Receiver Details

	Ch. 1	Ch. 2	Ch. 3	Ch. 4
RF-3dB Frequencies (MHz)	2750-2610	2750-2610	2750-2610	2750-2610
Receiver Noise Temperature (°K)	120	130	127	118
Calibration Noise Tube Temperature* (°K)	4.48	5.20	4.92	5.33
Feed Offset on Sky	Center	Center	10' West	10' East
Position Angle of Feed E-Vector (degrees)	0	90	135	45

*Typical values only. Values were different for some later runs.

resulted in amplitudes for the Gaussians represented by the antenna temperatures T_1, T_3, T_4 discussed in the next section. A detailed description of how measured antenna temperatures for the sources from the three feeds were obtained is given later in the chapter.

B. 11 cm Observations and Reduction Theory

Consider a source with total flux S_{tot} equal to an unpolarized flux S_u and polarized flux S_p with position angle χ. Then, in the x-y coordinate system defined in Figure III-1,

$$S_x = \frac{S_u}{2} + S_p \cos^2\chi \quad \text{(III-1)}$$

$$S_y = \frac{S_u}{2} + S_p \sin^2\chi \quad \text{(III-2)}$$

(Since the projections of the polarized E field on the x and y axes are proportional to $\cos\chi$ and $\sin\chi$, the fluxes due to the E fields along these axes are proportional to $\cos^2\chi$ and $\sin^2\chi$.) In the x'-y' coordinate system,

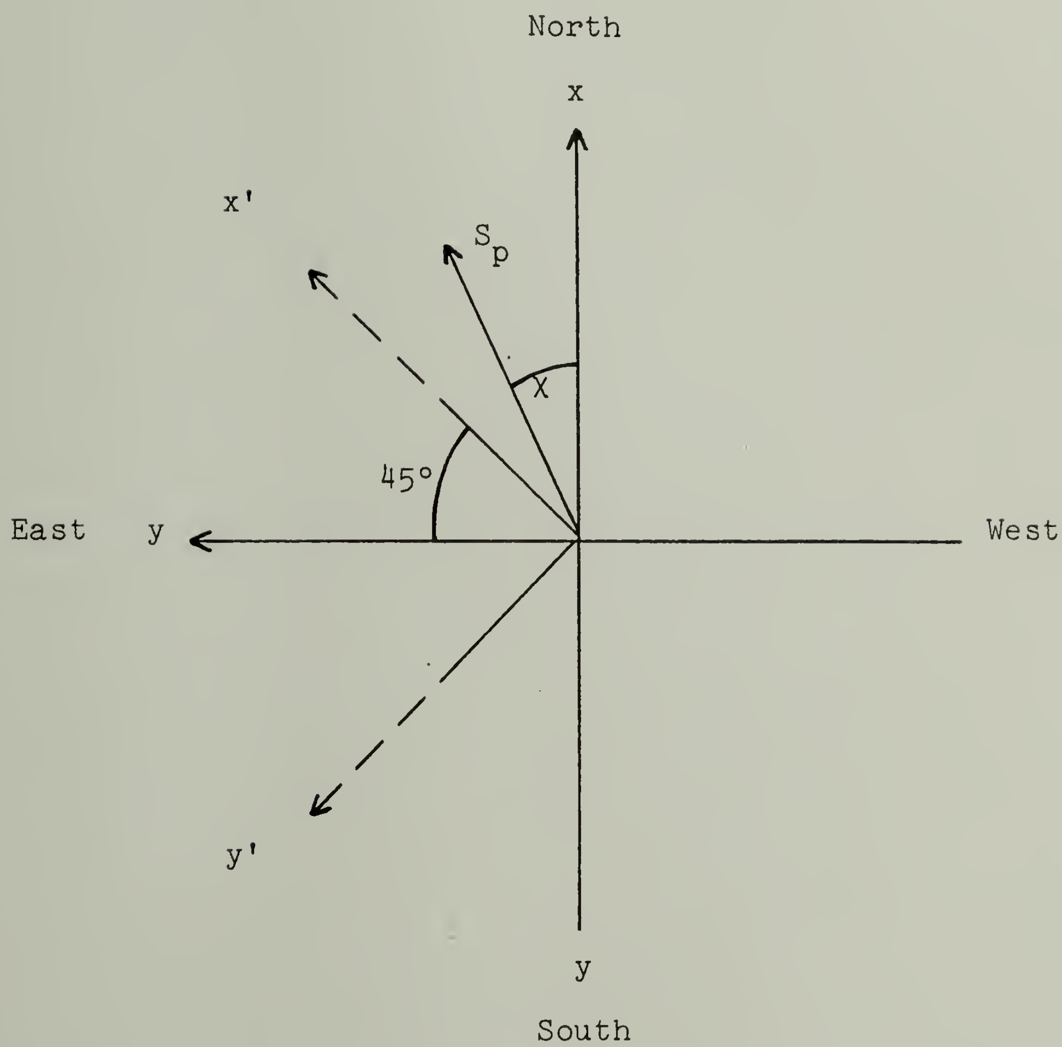
$$S_{x'} = \frac{S_u}{2} + S_p \cos^2(\chi - \frac{\pi}{4}) = \frac{S_u}{2} + \frac{S_p}{2}(1 + \sin 2\chi) \quad \text{(III-3)}$$

$$S_{y'} = \frac{S_u}{2} + S_p \sin^2(\chi - \frac{\pi}{4}) = \frac{S_u}{2} + \frac{S_p}{2}(1 - \sin 2\chi) \quad \text{(III-4).}$$

The powers measured in the vertical and horizontal dipoles of the center feed (channels 1 and 2), P_y and P_x respectively, are given by

Figure III-1

Coordinate System



$$P_x = \alpha(\frac{S_u}{2} + S_p \cos^2\chi) \tag{III-5}$$

$$P_y = \beta(\frac{S_u}{2} + S_p \sin^2\chi) \tag{III-6}$$

where α and β are constants of proportionality that depend on the efficiency of the antenna and feed to radiation.

Similarly, for the channel 3 pair of dipoles (position angle 135°),

$$P_{x'} = \gamma[\frac{S_u}{2} + \frac{S_p}{2}(1 + \sin 2\chi)] \tag{III-7}$$

$$P_{y'} = \zeta[\frac{S_u}{2} + \frac{S_p}{2}(1 - \sin 2\chi)] \tag{III-8}$$

where γ and ζ are constants of proportionality of the same nature as α and β.

The powers coming out of the center (polarization-switched) feed, P_Q, the west (polarization-switched) feed, P_U, and the east (load-switched) feed, P_S, are

$$P_Q \equiv P_x - P_y = (\alpha - \beta)\frac{S_u}{2} + S_p(\alpha\cos^2\chi - \beta\sin^2\chi) \tag{III-9}$$

$$P_U \equiv P_{x'} - P_{y'} = (\gamma - \zeta)\frac{S_u}{2} + (\gamma - \zeta)\frac{S_p}{2} + (\gamma + \zeta)\frac{S_p}{2} \sin 2\chi \tag{III-10}$$

$$P_S = \varepsilon \frac{S_u}{2} + \varepsilon \frac{S_p}{2}(1 + \sin 2\chi) \tag{III-11}$$

where ε is similar to α, β, γ, ζ. Defining the quantities ρ and σ as

$$\rho \equiv \beta/\alpha \; ; \; \sigma \equiv \zeta/\gamma$$

one can write the antenna temperatures observed in channels

1, 3, and 4 (T_1, T_3, T_4) as

$$kT_1 \equiv P_Q = \alpha(1 - \rho)\frac{S_u}{2} + \alpha S_p(\cos^2\chi - \rho\sin^2\chi) \tag{III-12}$$

$$kT_3 \equiv P_U = \gamma(1 - \sigma)\frac{S_u}{2} + \gamma(1 - \sigma)\frac{S_p}{2} + \gamma(1 + \sigma)\frac{S_p}{2}\sin2\chi \tag{III-13}$$

$$kT_4 \equiv P_S = \varepsilon\frac{S_u}{2} + \varepsilon\frac{S_p}{2}(1 + \sin2\chi) \tag{III-14}$$

Rearranging terms and recognizing that α, γ, ε are related to the 300 foot antenna's efficiency, which in turn is a function of the telescope's altitude (and hence, declination δ) leads to

$$(\frac{S_u}{2} + S_p\cos^2\chi) - \rho(\frac{S_u}{2} + S_p\sin^2\chi) = f_1(\delta)T_1 \tag{III-15}$$

$$(\frac{S_u}{2} + \frac{S_p}{2} + \frac{S_p}{2}\sin2\chi) - \sigma(\frac{S_u}{2} + \frac{S_p}{2} - \frac{S_p}{2}\sin2\chi) = f_3(\delta)T_3 \tag{III-16}$$

$$\frac{S_u}{2} + \frac{S_p}{2} + \frac{S_p}{2}\sin2\chi = f_4(\delta)T_4 \tag{III-17}$$

where $f_1(\delta) \equiv \frac{k}{\alpha}$; $f_3(\delta) \equiv \frac{k}{\gamma}$; $f_4(\delta) \equiv \frac{k}{\varepsilon}$.

In order to simplify data reduction, the quantities ρ and σ were taken to be independent of declination. In reality, there is some variation with declination in the gain ratios, resulting in a slight instrumental polarization. Rather than assume a form for $\rho(\delta)$ and $\sigma(\delta)$, correction for instrumental polarization was left to a later stage in the processing when the observations of many objects could be examined for evidence of this effect.

Equations III-15, III-16, and III-17 formed the basis for both the calibration of the system and the computation of results for the sources that were observed. Calibration of the antenna's response to polarized 11 cm radiation required making measurements with the polarization switching experimental setup of standard sources over a wide range in declinations. From measurements of T_1, T_3, T_4 for the standards (S_u, S_p, χ known), it was possible to obtain values for ρ, σ, $f_1(\delta)$, $f_3(\delta)$, and $f_4(\delta)$. (T_2, the channel 2 radiometer output and duplicate of T_1, was not used in the reduction procedure because of continuing equipment problems that made the channel 2 parametric amplifier several times noisier than that in channel 1.) This was done in the following manner.

Because there was only one unknown, $f_4(\delta)$, in equation III-17, it was possible to solve for $f_4(\delta)$ as closely as the limits of observational error allowed. It was determined from a least-squares fit of standard sources of known flux density to a fourth-order polynomial in declination. Lower order polynomials produced poorer fits to the observations, as determined from residuals, while the next higher order polynomial showed no improved fit on the basis of either residuals or visual inspection. The choice of a fifth-order polynomial would have produced a curve that was more assymetric about the zenith than was suggested by the data within 25 degrees of the zenith. The fourth-order curve was more in line with an extrapolation of behavior at lower declinations. Typically, 180 data points covering declinations from -19 to 80 degrees were used to calibrate an entire observing run.

The situation in equations III-15 and III-16 was different. Here there were two equations in four unknowns and an iterative procedure was necessary to determine ρ, σ, $f_1(\delta)$, and $f_3(\delta)$. For each of these two equations the same general procedure was followed. For equation III-15, an initial guess was made as to the value of ρ. Then III-15 was solved for $f_1(\delta)$ with a least-squares fit of the data to a fourth-order polynomial in declination, as was done with $f_4(\delta)$.

The $f_1(\delta)$ so determined was then used to calculate a better value of ρ. The equation used came from manipulating III-15 into III-18e as follows:

$$f_1(\delta)T_1 = (\frac{S_u}{2} + S_p \cos^2\chi) - \rho(\frac{S_u}{2} + S_p \sin^2\chi) \qquad \text{(III-15)}$$

$$f_1(\delta)T_1 = \frac{1 - \rho}{2}S_u + (\cos^2\chi - \rho\sin^2\chi)S_p \qquad \text{(III-18a)}$$

$$f_1(\delta)T_1 = \frac{1 - \rho}{2}S_u + [\frac{1 + \cos 2\chi}{2} - \rho\frac{1 - \cos 2\chi}{2}]S_p \qquad \text{(III-18b)}$$

$$2f_1(\delta)T_1 = (1 - \rho)(S_u + S_p) + (1 + \rho)S_p \cos 2\chi \qquad \text{(III-18c)}$$

$$\frac{2f_1(\delta)T_1}{(S_u + S_p)} = (1 - \rho) + (1 + \rho)\frac{S_p \cos 2\chi}{(S_u + S_p)} \qquad \text{(III-18d)}$$

$$\frac{S_p \cos 2\chi}{(S_u + S_p)} - \frac{2f_1(\delta)T_1}{(1 + \rho)(S_u + S_p)} = \frac{\rho - 1}{\rho + 1} \qquad \text{(III-18e)}$$

For each observation of a polarization standard (S_u, S_p, and χ known), the initial guess of ρ and the resultant $f_1(\delta)$ were used in III-18e to compute a value for the quantity $\frac{\rho - 1}{\rho + 1}$. This quantity was averaged over all standard source polarization observations to produce a better value of ρ, which was then fed back into III-15 for a new evaluation of $f_1(\delta)$. Iteration was continued until convergence, defined as successive values of ρ being no more than 1 part in 1000 different, was achieved.

As will be shown later (equations III-23 and III-24), the determination of the Stokes parameters Q' and U' for the unknowns required evaluation of the expressions $\frac{\rho - 1}{\rho + 1}$ and $\frac{\sigma - 1}{\sigma + 1}$, and it was for this reason that these quantities, rather than ρ and σ were solved for in the iteration.

The solution for the equation III-16 was somewhat different. It was apparent from examining the data that $f_3(\delta)$ was almost constant with declination in the interval from 0 to 60 degrees, where most of the primary polarization standards were located (see Figure III-2). Thus, equation III-16 was essentially one equation in two unknowns (σ and $f_3(\delta)$ = constant), lacked a unique solution, and would not converge. But by assuming values for σ from 1.05 to 1.15 and calculating for each σ the RMS deviation of the least-squares fit polynomial $f_3(\delta)$, it was found that best fits (using minimum RMS as a criterion) were obtained when σ was

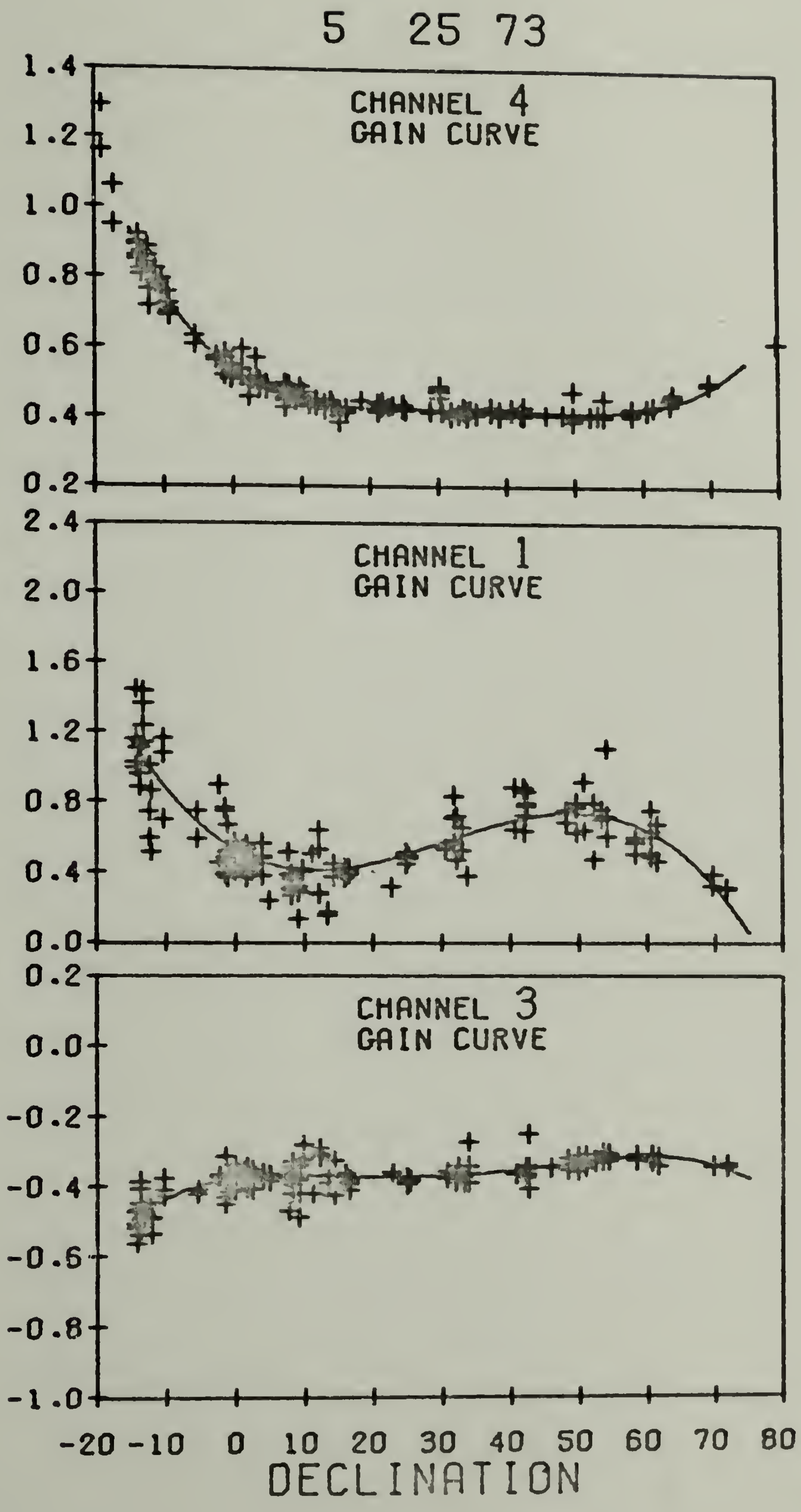


Figure III-2 Gain Curves

approximately 1.10 ± .02. So an initial value of $\sigma = 1.0975$ (the average of early estimates of the best σ for 5 runs in 1973) was assumed, and the iterative process used with III-15 was employed through 5 iterations with III-16. After secondary standards were added at very low declinations ($\delta < 0$) in the region where $f_3(\delta)$ was not a constant, σ did show convergence. In summary, the values of σ and ρ chosen gave good empirical fits to the observations.

As with $f_4(\delta)$, both $f_1(\delta)$ and $f_3(\delta)$ were taken to be fourth-order polynomials for essentially the same reasons. The curvature of $f_1(\delta)$ or $f_3(\delta)$ for $\delta \leq -10°$ could not have been accurately represented by a lower order polynomial. The scatter about the fitted curves were determined for later use in error propagation. Figure III-2 and Table III-2 show gain curves for a typical run and values for the feed parameters for each run. The functions $f_4(\delta)$ and $f_3(\delta)$ were of the same general shape: a broad maximum between 10 and 60 degrees declination, with reduced gain at lower and higher declinations. This effect was caused by gravity as it deformed the telescope's reflective surface at low elevations.

The curves $f_4(\delta)$, $f_3(\delta)$, and $f_1(\delta)$ described different characteristics of the 300 foot antenna. $f_4(\delta)$ measured the change in antenna efficiency with declination, decreasing at low elevations due to gravity induced changes in the focal point. $f_1(\delta)$ and $f_3(\delta)$, however, measured the changes in response of the antenna to polarized radiation as a function of declination. Gravitational loading of the 300 foot

Table III-2

Calibration Parameters

	ρ	σ
8-30-72	------	------
1-11-73	1.0348 ± 0009	1.0983 ± 0004
4-3-73	1.0423 ± 0007	1.1007 ± 0004
5-25-73	1.0379 ± 0009	1.0982 ± 0004
8-17-73	1.0385 ± 0009	1.0956 ± 0004
11-14-73	1.0388 ± 0007	1.0971 ± 0003
2-25-74	1.0385 ± 0009	1.1088 ± 0003
6-26-74	1.0344 ± 0010	1.1028 ± 0004
11-22-74	1.0502 ± 0010	1.1016 ± 0006
2-27-75	1.0496 ± 0013	1.1000 ± 0007
6-10-75	1.0482 ± 0012	1.0998 ± 0007
8-16-75	1.0405 ± 0007	1.1010 ± 0004
Averages	1.0412 ± 0017	1.1004 ± 0011

reflective surface made the telescope's efficiency to radiation polarized in the north-south plane about 4% greater than the efficiency to radiation polarized in the east-west plane. $f_1(\delta)$, associated with the center feed (polarization-switching between dipoles aligned north-south and east-west), was especially sensitive to this astigmatism. $f_3(\delta)$, associated with the feed 10' west of the center feed (polarization-switching between dipoles aligned with position angles 45° and 135°) was less sensitive to the astigmatism because both dipoles were affected equally (to first order). Only at low elevations did $f_3(\delta)$ depart significantly from a constant.

Having obtained σ, ρ, $f_1(\delta)$, $f_3(\delta)$, and $f_4(\delta)$, all that remained was to solve III-15 through III-17 in terms of these parameters and the measured antenna temperatures for S_{tot}, m, and χ. This can be done by rewriting III-15 through III-17 as

$$2f_1(\delta)T_1 = (1 - \rho)(S_u + S_p) + (1 + \rho)S_p \cos 2\chi \tag{III-19}$$

$$2f_3(\delta)T_3 = (1 - \sigma)(S_u + S_p) + (1 + \sigma)S_p \sin 2\chi \tag{III-20}$$

$$2f_4(\delta)T_4 = (S_u + S_p) + S_p \sin 2\chi \tag{III-21}$$

Combining III-20 and III-21 led to

$$S_{tot} \equiv S_u + S_p = \frac{\sigma + 1}{\sigma} f_4(\delta)T_4 - \frac{1}{\sigma}f_3(\delta)T_3 \tag{III-22}$$

Then $(S_u + S_p)$ in III-22 was substituted in III-19 and III-20 leading to

$$Q' \equiv \frac{S_p \cos 2\chi}{S_u + S_p} = \frac{2f_1(\delta)T_1}{(1 + \rho)(S_u + S_p)} + \frac{\rho - 1}{\rho + 1} \quad \text{(III-23)}$$

$$U' \equiv \frac{S_p \sin 2\chi}{S_u + S_p} = \frac{2f_3(\delta)T_3}{(1 + \sigma)(S_u + S_p)} + \frac{\sigma - 1}{\sigma + 1} \quad \text{(III-24)}$$

$$m = 100 \frac{S_p}{S_u + S_p} = 100(Q'^2 + U'^2)^{1/2} \quad \text{(III-25)}$$

$$\chi = \frac{1}{2} \mathrm{TAN}^{-1}(U'/Q') \quad \text{(III-26)}$$

Equations III-22 through III-26 were then used to determine for each source observation the total flux, S_{tot}, the polarized flux, S_p, the normalized Stokes parameters, Q' and U', the degrees of polarization, m, and the position angle, χ. Standard techniques for propagating errors through the equations led to expressions for S_{tot}, $\Delta Q'$, and $\Delta U'$ in terms of errors in the observed antenna temperatures and in the calibration results.

An attempt was made to use as many standard objects as possible in calibrating the system. Standards were chosen from the literature to give maximum coverage over the range of declinations observed. Table III-3 shows the standards chosen along with their original values and literature references (for primary standards) and final adjusted values for all. The total number used was 84: 75 for calibrating the load-switching channel and 55 of the 84 for the polarization-switched channels. This difference in number was due to the fact that there were many more published values of source flux densities without polarization data than there were sources with complete information available. Since most radio sources pos-

Table III-3

Source	δ(1950)	Original Values S_{tot} (Jy)	m (%)	χ (degrees)	Reference	Final Values S_{tot} (Jy)	m (%)	χ (degrees)
3C9	15.4					1.02		
3C10	63.9					34.6		
0026+34 (OB343)	34.7					1.64		
3C17	-2.4	3.83			KPT*	3.75	0.4	161.5
0056-00	-0.2	1.88	5.0	88.0	WK	1.86	4.6	91.7
0106+01	1.3	(2.96)	1.6	109.0	AL	(3.29)	1.2	111.7
0122-00	-0.4					1.12		
3C48	32.9	8.94	1.8	71.0	AL	9.87	1.8	78.1
3C52	53.3	2.30			KPT*	2.33	2.1	117.4
0202-17	-17.3					1.70		
3C62	-13.2					2.80	10.0	94.1
0223+34	34.1					1.82		
0256+07 (OD094.7)	7.6					0.80		
3C78	3.9	5.05	3.0	98.0	GMW	5.10	1.8	99.6
0325+02	2.4	2.90	5.2	101.0	GMW	3.33	3.5	97.1
0333+32 (NRAO140)	32.1	(2.87)	1.8	94.0	AL	(3.13)	2.6	94.3
3C93.1	33.7	1.28			KPT*	1.37	0.0	-----
NRAO150	50.8	(5.41)	1.7	116.0	AL	(5.66)	2.5	103.0
3C109	11.1					2.43	2.4	49.0
0420-01	-1.5	(1.19)	2.1	74.0	AL	(1.17)	2.3	82.5

Table III-3 (Continued)

Source	δ(1950)	Original Values S_{tot} (Jy)	m (%)	χ (degrees)	Reference	Final Values S_{tot} (Jy)	m (%)	χ (degrees)
0428+20	20.5					3.22		
3C132	22.7					2.05	7.3	174.8
0518+16	16.6	5.62	9.8	169.0	WK	5.87	9.6	173.6
3C144	22.0					788.		
3C145	-5.4	379.	0.0	-----	GMW	378.	0.0	-----
3C147	49.8	12.67	0.1	69.0	AL	12.20	0.3	129.9
054 +18 (4C18.16)	18.7					1.28		
3C158	14.6	1.11			KPT*	1.11		
3C161	-5.9	11.06	10.1	173.0	GMW	10.97	10.5	
3C166	21.4	1.69			KPT*	1.57		
3C171	54.2	2.00	7.3	113.0	MS	1.99	6.0	113.0
0703+42 (4C42.23)	42.6					1.77	2.8	77.8
0711+35 (OI318)	35.7					1.96		
0742+10	10.3					3.86		
3C190	14.4	1.38			KPT*	1.39	0.0	-----
3C196	48.4	7.66	2.4	71.0	MB	7.81	1.2	72.6
0859-14	-14.1	(2.70)	2.8	90.0	AL	(3.02)	4.3	92.9
0906+01	1.6					0.83		
3C218	-11.9					23.9	0.7	91.5
3C219	45.9					4.35	2.5	138.5

Table III-3 (Continued)

Source	$\delta(1950)$	Original Values S_{tot} (Jy)	m (%)	χ (degrees)	Reference	Final Values S_{tot} (Jy)	m (%)	χ (degrees)
3C226	10.0	1.17			KPT*	1.08	5.8	86.7
M82	69.9	5.59	3.5	35.0	MB, KPT*	5.03	0.8	16.1
3C234	29.0					3.20		
3C237	7.7	3.66			KPT*	3.51	0.0	-----
3C244.1	58.5	1.95			KPT*	1.97	5.8	96.0
3C245	12.3					2.20	7.7	46.1
3C246	-9.0					1.35		
1055+01	1.8	(2.76)	4.2	88.0	AL	(2.84)	4.0	91.7
3C254	40.9	1.44	2.3	94.0	WK	1.55	3.8	93.3
1136-13	-13.6					3.07	0.9	54.9
1148-00	-0.1					2.32		
1150+49 (4C49.22)	49.8	1.59	3.1	113.0	WK	1.45	4.3	109.3
3C268.3	64.5	1.98			KPT*	2.01		
1237-10	-10.1					1.50	4.3	78.0
1241+16	16.7	1.72			WK	1.71	1.9	119.0
3C287	25.4	4.54	4.0	114.0	AL	4.93	3.9	108.3
3C286	30.8	12.13			WK	11.29	9.6	25.8
3C288	39.1	1.76			KPT*	1.88		
1354-15 (OP-192)	-15.2	(1.74)	2.4	101.0	AL	(1.56)	3.6	97.6
3C295	52.4	11.83			KPT*	12.18	0.1	96.9

Table III-3 (Continued)

Source	$\delta(1950)$	Original Values S_{tot} (Jy)	m (%)	χ (degrees)	Reference	Final Values S_{tot} (Jy)	m (%)	χ (degrees)
3C298	6.7					2.77		
1434+03	3.6					1.82		
1453-10	-10.9					2.43		
3C309.1	71.9	(5.30)	2.4	102.0	WK	(5.17)	0.4	85.5
3C317	7.2	2.11			KPT*	2.13		
1539-09	-9.3					0.98		
3C348	5.1	27.10			GMW	25.4	3.8	34.7
3C365	13.5	1.28			KPT*	1.33	1.0	140.5
3C390.3	79.7	6.56			KPT*	6.75		
3C391	-1.0	16.46	0.4	144.0	GMW	15.82	0.5	2.9
3C395	31.9	2.58			KPT*	3.14	5.7	173.5
3C399.1	30.2					1.74		
3C401	60.6	2.76	3.8	89.0	MS	2.63	1.7	86.4
3C409	23.4	6.44			KPT*	6.80	0.0	-----
2021+61 (OW637)	61.5					2.14	0.4	80.6
DR21	42.2	14.78	0.0	-----	ALLER†	15.44	0.0	-----
NGC7027	42.0					3.72	0.0	-----
3C433	24.9	6.49	5.4	121.0	GMW	6.84	6.1	107.2
2128-12	-12.3	1.67	0.7	123.0	WK	1.69	2.4	96.7
3C438	37.8	3.33			GMW	3.47		

Table III-3 (Continued)

Source	δ(1950)	Original Values S_{tot} (Jy)	m (%)	χ (degrees)	Reference	Final Values S_{tot} (Jy)	m (%)	χ (degrees)
2209+08	8.1	1.51	4.2	86.0	WK	1.34	4.5	88.7
3C454.3	15.9	(10.37)	5.6	160.0	GMW	(10.67)	6.0	168.4
2300-18	-19.0					0.99		
3C456	9.1	1.33			KPT*	1.37	0.8	46.8

Reference Key

AL	Altschuler, 1974
ALLER†	Aller, 1970a
GMW	Gardner, Morris, and Whiteoak, 1969
MB	Morris and Berge, 1964
MS	Maltby and Seielstad, 1966
KPT*	Kellerman, Pauliny-Toth, and Tyler, 1968
WK	Wardle and Kronberg, 1974

sess low degrees of polarization, it was decided to take the available flux density information for all sources in the list of primary standards, assume zero polarization for sources lacking polarization information, and accept the scatter resulting from underestimating some of the sources' polarized fluxes. Examination of equation III-17 indicated that such a procedure would underestimate the $f_4(\delta)$ values by an amount ranging from zero to twice the standard source's true degree of polarization. Only one third of the standards used to determine $f_4(\delta)$ fell into this category, and they were distributed uniformly in declination being intermixed with twice as many standards of known polarization properties. In addition, most of them had total fluxes under 2 Jy and degrees of polarization under 3 per cent. As a result, the effect of the underestimation was inconsequential. Thus, there were more points at more declinations for a better determination of $f_4(\delta)$ through this approximation, and even with the uncertainty, the scatter of points about the f_4 polynomial was several times smaller than the scatters associated with the other two gain functions.

The large number of standards was also helpful in calibrating channels 1 and 3 because of the significant scatter in the points that initially defined those two calibration curves. The scatter was due to two factors. First, random errors due to noise introduced an uncertainty in T_i's and hence the determination of the calibration curves.

Secondly, there were systematic deviations from the least square calibration curve shape for groups of points representing several measurements of the same source. These deviations of groups of points indicated inaccuracies in the polarization values measured and published by other investigators and used as primary standards in this study. While the first source of scatter was unavoidable, the second could be minimized by using as many primary standards as possible to determine the initial calibration curves and then using those curves to revise measurements of the standard sources into a self-consistent set. Because of a scarcity of standard sources in some declination intervals, it was necessary to include as standards some sources known to be variable at higher frequencies but with published polarization measurements during the time of this study. If some of these standard sources varied in polarization from run to run, their variations would have been small enough not to affect any run's calibration curves significantly. One of the standard sources known to be flux density variable (and hence used just for polarization calibration), 3C454.3, showed polarization variations of 1 per cent in m around a mean of 6 percent. This variation did not affect the calibration significantly, however, because of the constant polarization standards at adjoining declinations (3C245 and 0518+16) and the high degree of constant polarization in 3C454.3, itself. The other flux density variables used for polarization calibration generally varied by no more than 0.5 per cent in m and 10 degrees in χ about mean values, variations only slightly above the noise level.

Analysis of the final values for the flux densities of the other primary standards over the 2.5 years of observation indicated possible flux density variations in six of the sources. Four (3C78, 1150+49, 3C287, and 3C433) showed only marginal evidence of variability while two (3C395 and 2209+08) were probably variable.

The flux densities of several other sources at declinations near 3C395 ($\delta = 32°$) and 2209+08 ($\delta = 8°$) showed no variations. This eliminated the possibility that a time dependent calibration curve (resulting from the use of variables as standards) had introduced spurious variations in radio sources that were actually constant. The use of a large number of flux standards had eliminated the effects of the few variables.

The primary standard source 3C161, although constant in flux and position angle, showed evidence of 4 per cent variation in m about a mean value of 10.5 per cent over the 2.5 years of observations. Once again, measurements of sources with similar declinations were examined to determine whether or not the polarization variations of 3C161 had affected the calibration curves and produced spurious polarization variations. The conclusion was that 3C161 had not affected the curves.

The revision of primary standard values to a self-consistent set was done by using the original values as standard values for five runs in 1973 and averaging the output of the reduction procedure for each source over all five runs. These revised values were then used as standards and the process repeated. After two more iterations, the standard values stopped changing and were adopted as the permanent set of primary standards.

The differences between the original and final values of Q' and U' for the primary sources were randomly scattered about 0 with

$$(Q'_{original} - Q'_{final})_{average} = .0016 \pm .0022$$

and

$$(U'_{original} - U'_{final})_{average} = -.0009 \pm .0017.$$

Using these primaries, the entire 2.5 years of data were reduced and inspected. The flux and polarization properties of sources that showed little evidence of variation were averaged over the accumulated runs. These sources were then combined with the primary standards to provide even better definition of the calibration curves. Thus, the 51 primary standards were augmented by 33 secondary standards.

The difference between the initial values of the secondary standards and their final values (averaged over all of the runs) agreed to within the expected accuracy of the measurements. In other words, the addition of the secondary standards did not significantly alter the calibration of the system, but instead served to strengthen it. Two of the secondary standards (0256+07 and 0906+01) showed marginal evidence of flux density variability, but as for the primary standard possible variables, there was no evidence that their variations had introduced spurious variations into constant sources. Chapter 4 will discuss these two sources more fully.

The second source of scatter in the calibration curves, removed through the above revision procedure, was important in determining the absolute error in this study's measurements. But it was only the irremovable observational errors that were important within the framework of the revised set of standards. Both sources of error will be discussed in the next chapter.

C. Data Reduction

Because of the relatively large amounts of observing time available in a seven day run, source selection was less restricted than it might have been. In 24 hours of observing 130 or so sources could be observed, so not only could sources known to be variable at shorter wavelengths be included, but also those with peculiar spectra, those suspected of being variable, and some about which nothing was known. Interspersed with these radio sources were the standard sources. In all, there were about 230 different sources observed. Because the 300 foot telescope is a transit instrument and cannot track sources for long, it was necessary to let them drift through the three beams. Since two highly desirable sources may have similar right ascensions (e.g., 3C273 and 3C274), and since the telescope can change declinations no faster than 10 degrees per minute, it was necessary to observe all of the sources in two consecutive 24 hour periods. While many of the sources were the same in the two 24 hours, some appeared in only one of the two periods. This 48 hour cycle was repeated throughout the observing run. Between source measurements were noise tube firings used to calibrate the source antenna temperatures.

The 300 foot antenna is highly automated in that for each source one need only type LST times corresponding to the start and stop times of observation and the source's declination (as well as parameters relating to the noise tube firings, feed box rotation, etc.) into the ddp-116 computer. A deck of cards covering observations for the full 48 hours was punched up and fed into the computer.

The data processing was performed at the University of Massachusetts Research Computing Center, initially on a CDC 3800, and finally on a CDC Cyber 7000 series computer. The processing took place in three stages.

Stage I performed the initial task of converting the telescope scans into antenna temperatures for each of the radiometer channels. As a source drifted through each of the three beams, the radiometer output was a series of antenna temperatures characteristic of a convolution of the beam shape with the source brightness distribution. For a point source the convolution resulted in an approximately Gaussian distribution of antenna temperatures during the drift through the beam with a half-width characteristic of the beam itself. For an extended source with Gaussian brightness distribution, the resultant Gaussian had a somewhat larger half-width. For each drift scan, the first stage reduction program fit a least-squares Gaussian to the data in each of the four channels. The first Gaussian fit was to the data in channel 4, the load-switched feed. The output of the subroutine included the Gaussian amplitude, peak position, half-width, and rms noise. Since the other three channels were polarization-switched, and hence would have Gaussians of much smaller amplitude than channel 4, the peak position of the channel 4 Gaussian was combined with the measured separation of the three feeds and the computed half-width of the channel 4 beam to provide an educated first guess as to the location of the Gaussian peaks in the polarization-switched channels. This was especially important in nearly unpolarized, weak sources, where the iterative process in the least-squares Gaussian subroutine would not converge without a good initial choice of the best peak position. It was found through analysis of computer-generated artificial observations that the Gaussian fitting subroutine tended to overestimate the amplitudes of drift scans by up to 5 per cent when the signal to noise ratio was less than 4. Because only a few observations fell into this category, and because hand reduction of those scans would have led to equally large uncertainties in the scan amplitudes, only total flux densities for these sources will be presented.

The output for each scan was a printed summary of all the data in each channel and the parameters found from the least-squares fit: Gaussian amplitude and peak position, half-width, base level, and rms noise. The above data for all four channels was also punched on two computer cards for use in the next stage of processing. A week's run usually produced a box of roughly 2000 cards. One of the two computer cards per scan had the scan number, source name, sidereal time of observation, apparent declination, and the four channel peak temperatures plus errors. The other card contained data on the Gaussian half-width for channel 4 plus the peak positions for all 4 channels. Because of the small amplitudes of the sources in the polarization-switched channels, greater accuracy was obtained if one used the half-width in the load-switched channel as the half-width in channels 1, 2, 3. Thus, in the polarization-switched Gaussians, the only variable parameters were amplitude and peak position.

The data on the second card of each scan, while of no immediate use in the next stage of reduction, was valuable in two regards. First, the peak position data for the three feeds showed close (although not perfect) agreement to what one would expect from the geometry of the three feeds. This was important in deciding to leave peak position a variable parameter during the least-squares fitting process. Secondly, the half-width from channel 4 of each source's scan provided a means of making later corrections to the data for sources that were extended.

While most of the sources in the program were point sources with respect to the 5 arcminutes beam, a few were somewhat extended. A source size correction factor (see Dent and Haddock, 1966), defined as

$$C_s \equiv \frac{R_\alpha \ R_\delta}{B_\alpha \ B_\delta} \qquad \text{(III-27)}$$

where R_α, R_δ are response widths in α, δ

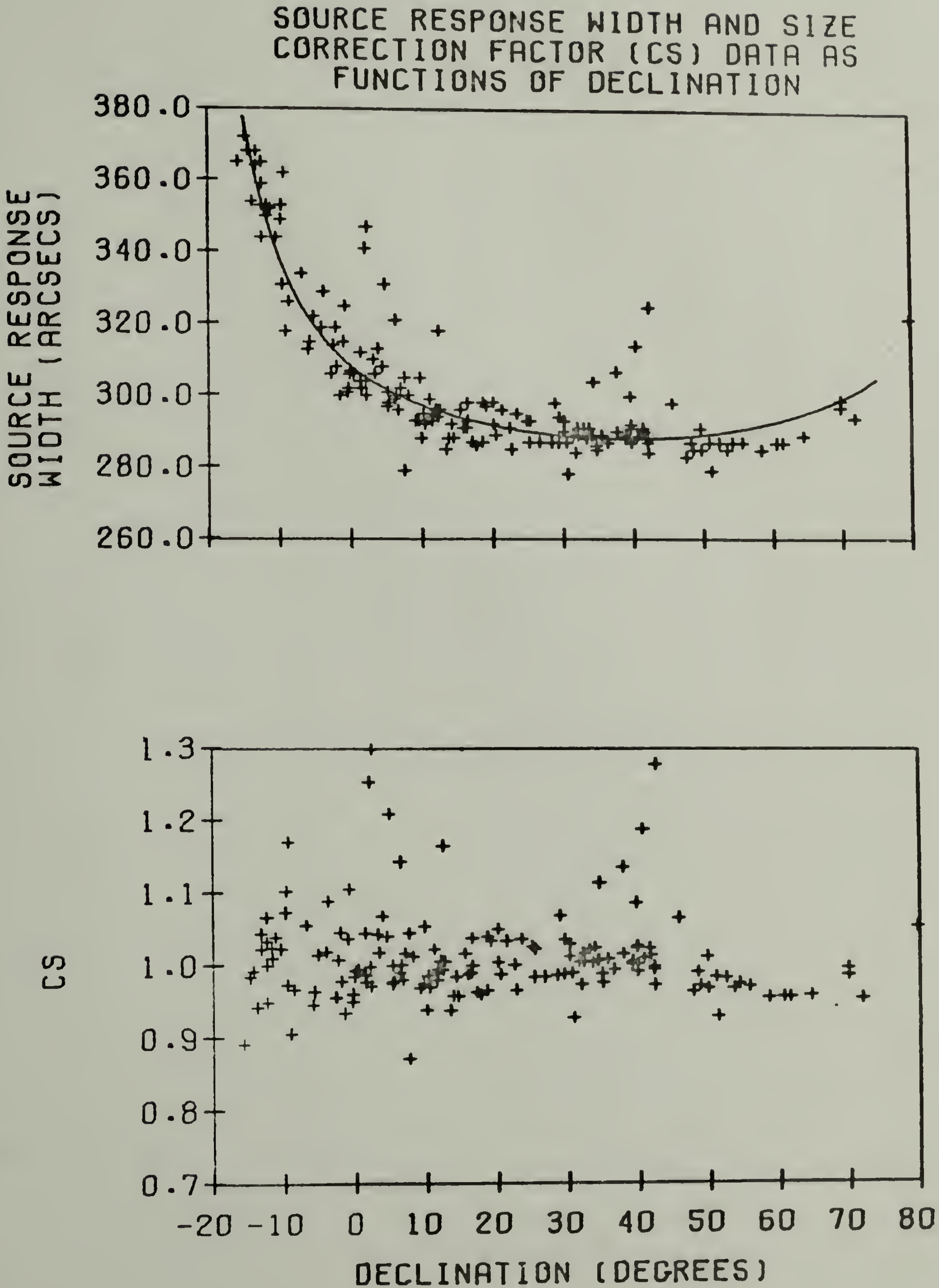
B_α, B_δ are beamwidths of the telescope in α, δ was calculated for the extended sources. This was done by plotting the non-extended sources' response widths (averaged over 5 runs) against declination and fitting an equation of the form

$$B_\alpha = a*\sec(Z) + b*\sec^2(Z) + c*\sec^3(Z)$$

where Z is the zenith distance

to the points (see Figure III-3). This line was then taken as representing the channel 4 beamwidth in right ascension as a function of declination and was not a constant because the dish deforms astigmatically. The squared ratio of R_α/B_α was taken to be the best estimate of source size the source size correction factor since the response widths in declination could not be measured. All values of C_s less than or equal to 1.050 were set equal to 1.000 to take into account

Figure III-3


SOURCE RESPONSE WIDTH AND SIZE CORRECTION FACTOR (CS) DATA AS FUNCTIONS OF DECLINATION
SOURCE RESPONSE WIDTH (ARCSECS)
380.0
360.0
340.0
320.0
300.0
280.0
260.0
CS
1.3
1.2
1.1
1.0
0.9
0.8
0.7
-20
-10
0
10
20
30
40
50
60
70
80
DECLINATION (DEGREES)

the noise in the determination of $B_\alpha(\delta)$ and $R\alpha$. These source size correction factors may be off by up to a factor of C_s or more. Still, only 30 out of 160 sources were found to have significant C_s's (see Table III-4 for sources with $C_s > 1$), and even should these be in error, that error will only affect the absolute value of the source's flux density. The per cent polarization and position angle, as well as the normalized Stokes parameters Q' and U', will be independent of C_s; and even though flux density comparisons with other works may be troubled by inconsistent C_s's, searches from run to run of this program for flux density and polarization variations will not be hindered. Hence, the errors in the determination of C_s's, typically three per cent internal error, were not included in the error propagation for any of the polarization properties measured. They will only be included in the absolute error.

Having obtained computer card output on the peak antenna temperatures for all four channels for each source measurement in a run, the next stage was to calculate flux density and polarization data from the observations. This was done by making two passes through the data. The first pass searched through the data for all observations of the standard objects and computed calibration constants ρ and σ and calibration curves $f_1(\delta)$, $f_3(\delta)$, and $f_4(\delta)$(see equations III-19 through III-21). The second pass through the data computed flux density and polarization properties for all

Table III-4

Source Size Corrections for Extended Objects

Source	$\delta(1950)$	C_s
0008+34	34.4	1.114
3C10	63.9	2.672
0048-09	-9.8	1.102
0202-17	-17.3	1.230
3C78	3.9	1.068
0325+02	2.4	1.298
3C136.1	24.9	2.272
3C144	22.0	1.416
3C145	-5.4	1.466
0703+42 (4C42.23)	42.6	1.278
0859-14	-14.1	1.094
3C219	45.9	1.066
0932+02	2.3	1.252
3C234	29.0	1.069
3C246	9.0	1.170
1106+37 (4C37.29)	37.9	1.136
3C274	12.7	1.165
1306-09	-9.6	1.073
1317-00	-0.6	1.106
1434+03	3.6	1.143
3C348	5.1	1.209
M17	-16.2	2.025
3C390.3	79.7	1.054
3C391	-1.0	1.602
3C405	40.6	1.188
2008-06 (OW015)	-6.9	1.057
2216-03	-3.8	1.089
2243-12 (OY-172.6)	-12.4	1.067

sources.

After all of the runs have been processed and the results written on a magnetic tape, the third stage program accumulates all the measurements for a source made in all the runs, sorts them out into groups of points made in each run, calculates average values of flux density Q', U', vector averages of the per cent polarization and position angle, and overall averages of all of these quantities for all the runs. The results for each source are printed out along with small graphs.

After the preliminary data reduction described above had been completed, a search was made for possible systematic polarization effects in the measured Q' and U' values for the sources. This was done by taking all essentially unpolarized sources (with $m \leq 1\%$), averaging their Q' and U' values, respectively, over 10 degree intervals in declination. A graph (see Figure III-4) showed systematic variations in the Q' and U' Stokes parameter of weakly polarized sources ($m \leq 1\%$) with declination. This effect was a combination of the antenna's instrumental polarization and the failure to define the polarization channel gain curves accurately enough. More polarization standards would have better defined the actual shapes of the gain curves and resulted in more accurate fourth-order polynomial approximations to the actual behavior of the telescope. Secondly, the fourth-order polynomials used were never considered to

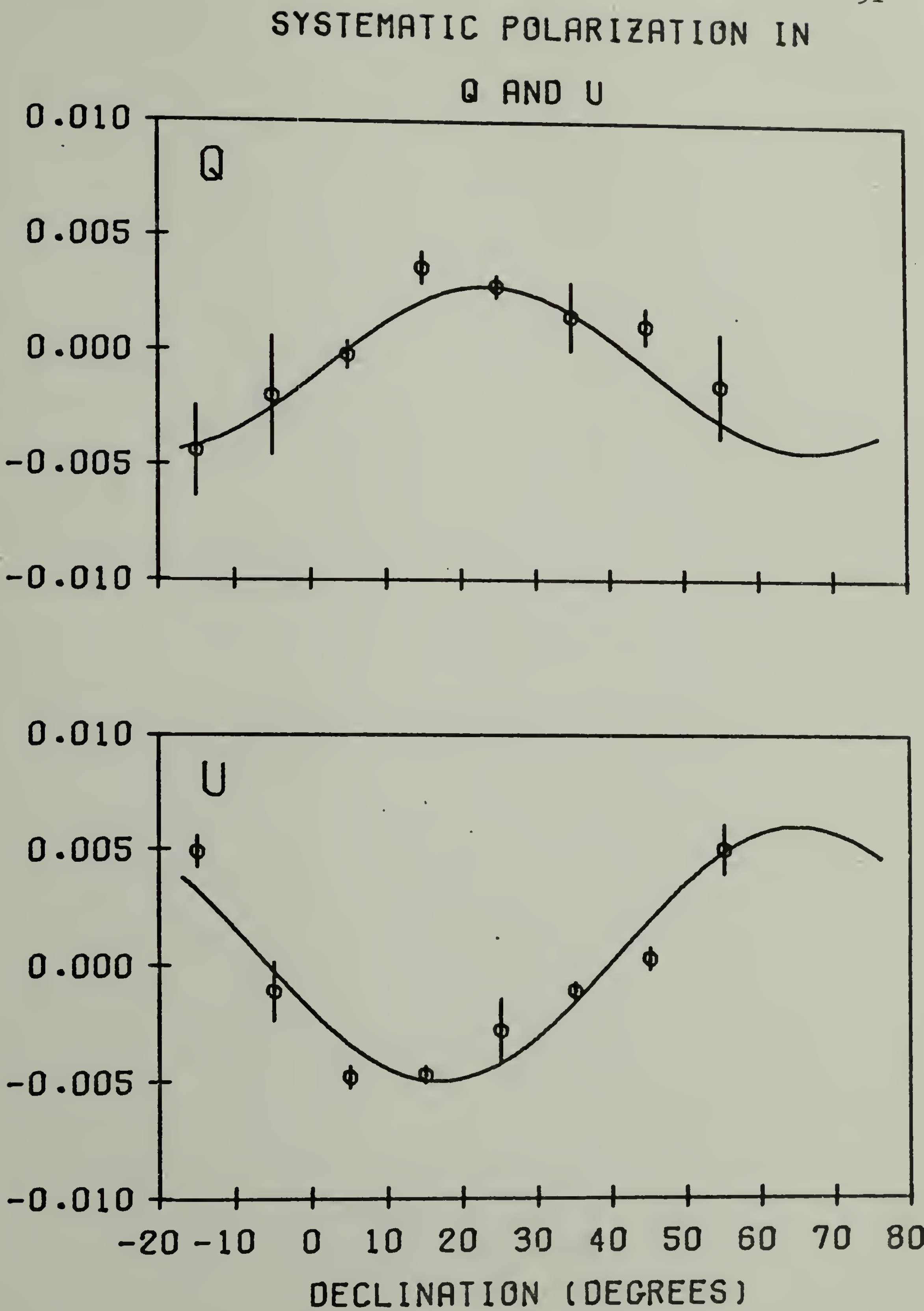

SYSTEMATIC POLARIZATION IN
Q AND U
Q
U
0.010
0.005
0.000
-0.005
-0.010
-20 -10 0 10 20 30 40 50 60 70 80
DECLINATION (DEGREES)

Figure III-4

be more than approximations to the true gain functions. Polynomials of any order have a degree of inflexibility that is only reduced by moving to higher order polynomials, and the scatter in the calibration data did not justify this. Curves of the form

$$A + B \sin(C\delta + E)$$

were fit to the data points and were used to remove this residual source of systematic polarization.

The observational difficulties encountered in taking the data were relatively minor. Pointing, a source of concern in large telescopes at short wavelengths (e.g., the 2 cm work at the Haystack Observatory) was not as critical in the 11 cm program, because the 300 foot telescope beamwidth at 11 cm is nearly 5 arcminutes. Positions for most of the sources in the program were known to 10" - 20" and some were much better (VLBI positions), resulting in negligible contribution to pointing error. Systematic deviations from the standard telescope pointing curve of up to 40 arcseconds (a function of declination) were calibrated out of the observations since they were combined with the aperture efficiency changes in the calculation of $f_4(\delta)$, $f_3(\delta)$, and $f_1(\delta)$. Lastly, as examination of equations III-23 through III-26 shows, pointing errors did not affect the computation of the quantities Q', U', m, and χ. As a result a minimum of time was spent in making pointing checks. Only enough information was gathered to determine that the pointing was not grossly in error.

Electronic equipment problems were minimal. The only continuing difficulty has been that the channel 2 paramp was roughly twice as noisy as the channel 1 paramp and would occasionally go into oscillations requiring the adjustment of its power supply. However, since channel 2 was a mirror image of channel 1, no essential data was lost.

Weather was also a minor problem at 11 cm. The biggest concern was gusting wind acting as a source of random pointing errors. The only recourse during high winds was to stop observing, and, during occasional gusting weather, to make enough measurements of each source in a week's observing run so that a deviant point would be obvious and could be rejected. At 11 cm infrequent rain and snow posed few problems.

The first observing run in this program was conducted in August 1972. Difficulties in setting up the polarization-switching radiometers at the time resulted in only acquiring useful data from the channel 4 (load-switching) radiometer. For each source observed during that and subsequent runs averaged polarization properties from this program's 2.5 years of measurements were combined with the channel 4 data to produce total fluxes from the August 1972 data.

D. Error Determination

Errors were determined for each measurement of S_{tot}, Q', and U' within a run by taking the measured errors in T_1, T_3, and T_4, combining them with the uncertainties in $f_1(\delta)$, $f_3(\delta)$, $f_4(\delta)$, σ and ρ, and then using equations III-22 through III-24 to propagate these original errors into ΔS_{tot}, $\Delta Q'$ and $\Delta U'$. From all measurements of a source in a given run, the average internal error was computed, as well as the standard deviation about the mean for $\overline{S}_{tot}$, $\overline{Q}'$, and $\overline{U}'$. Because many sources were not observed more than three times in a run, and because the standard deviation determined from three points or less was not statistically meaningful, empirical formulae were devised for ΔS_{tot}, $\Delta Q'$, and $\Delta U'$ for sources with fewer than four measurements in a run. This was done by examining the errors in the determination of S_{tot}, Q', and U' for sources with four or more individual measurements whose flux densities and declinations covered a wide range. The formulae developed were

$$(\Delta S_{tot})^2 = \frac{1}{N}[(.035)^2 + (.014\ S_{tot})^2 + 2.8 \times 10^{-17} z^8 S_{tot}^2] \qquad \text{(III-28)}$$

$$(\Delta Q')^2 = \frac{1}{N}[(\frac{.022}{S_{tot}})^2 + (.005)^2] \qquad \text{(III-29)}$$

$$(\Delta U')^2 = \frac{1}{N}[(\frac{.008}{S_{tot}})^2 + (.002)^2] \qquad \text{(III-30)}$$

where N is the number of measurements

z is the zenith distance of the source

ΔS_{tot} is in units of Janskys

$\Delta Q'$ is dimensionless

$\Delta U'$ is dimensionless

The first term in III-28 represented the contribution of noise in the radiometer to the uncertainty in S_{tot} and was independent of source strength. The second term described the uncertainty due to receiver or antenna gain changes and was a constant percentage of the total flux. The third term in III-28 described a contribution to the error in S_{tot} that was zenith distance (hence, declination) dependent, and was a variable percentage of the total flux. The term arose from pointing errors that became more serious as zenith distance increased. At large zenith distances this term dominated the error. The term stemmed from the response of the antenna gain to a pointing error Δx:

$$S_{measured} = S_{true} \exp[-2.77(\frac{\Delta x}{B})^2] \qquad \text{(III-31)}$$

where B is the half-power beamwidth of the antenna

$S_{measured}$, S_{true} are the measured and true flux densities of a point source

So, for $\Delta x \ll B$,

$$\frac{\Delta S}{S} \equiv \frac{S_{measured} - S_{true}}{S_{true}} \approx 2.77(\frac{\Delta x}{B})^2 \qquad \text{(III-32)}$$

$$(\frac{\Delta S}{S})_{pointing} \propto (\Delta x)^2 \qquad \text{(III-33)}$$

Since pointing corrections for the 300 foot telescope varied quadratically with zenith distance, it was reasonable to suppose that errors in pointing varied with z^2. Thus

$$\left(\frac{\Delta S}{S}\right)_{\text{pointing}} \propto z^4 \qquad \text{(III-34)}$$

Using strong sources at several zenith distances, rough agreement with a z^4 dependence was found.

For sources with fewer than four measurements in a run, equation III-28 was used to estimate ΔS_{tot}. While the error in flux density may have been worse for some sources due to special problems (baseline difficulties, large pointing errors, noise tube calibration inaccuracies, etc.), III-28 represented the uncertainty in S_{tot} more accurately than would the scatter in one to three points. The computed standard deviation of the mean was used for sources with four or more measurements in a run.

The forms of equations III-29 and III-30 were similar. In each, the error was the sum of two quadratically-added terms: one was a constant percentage of S_{tot} resulting from gain fluctuations, and the other term was the contribution of receiver noise. A term due to systematic pointing errors was not necessary, since U' and Q' were independent of small positional inaccuracies. For $N < 4$ equations III-29 and III-30 were used to represent the error in $\overline{Q}'$ and $\overline{U}'$ for a run. For $N \geq 4$, the computed scatter itself was used. The one chosen was then compared against the average internal error, and the larger of the two taken as representing the uncertainty in $\overline{Q}'$ and $\overline{U}'$ for a source in a given run. The errors $\Delta Q'$ and $\Delta U'$ were then used to determine the errors in the degree of polarization and in the position angle.

The absolute error in the measurements of S_{tot} for a given source depended on two quantities: the flux density scale chosen and the uncertainty in C_s. Most of the primary flux density standards were taken from an 11 cm survey by Kellerman, Pauliny-Toth, and Tyler (1968) that was part of a flux density scale defined by Kellerman, Pauliny-Toth, and Williams (1969). When their values were adjusted slightly to form a self-consistent set of calibrators along with flux standards from other references, the flux density scale may have changed slightly, although it remained within 2 to 3 percent of that defined by Kellerman et al. In any case, a difference in scales would not affect the measurement of variability since it was systematic. In the calculation of radio spectra, this uncertainty added a 2 to 3 percent error in their determinations. As noted earlier, the calculated source size corrections (C_s's) may be in error by up to a factor of $\sqrt{C_s}$ or more, and so the flux density measurements would also be off by the same amount. Thus, such sources' 11 cm flux densities must be used cautiously in the determination of spectra.

Before discussing the 11 cm observations in the next chapter, their reliability should be examined briefly. Care has been taken in reducing the twelve runs to minimize the possibility of systematic effects. The errors in S_{tot}, Q', and U' for individual measurements, averages for a single run, and averages over all runs have been carefully estimated to take into account all known sources of error. Examination of the final values for S_{tot} and U' show no sign of being biased by effects of an unexplained nature. However, the Q' values for some sources with declinations less than zero suggest the possibility of calibration problems in the center, polarization-switched feed. This has manifested itself in the similar time variations in m and χ for several sources at low declinations (0405-12, 0727-11, 1510-08, 3C446, and 2243-12). While coincidences do happen, and although several sources at similar declinations do not share the same form of temporal variations, it would be prudent to keep in mind the possibility of systematic effects when examining the polarization behavior of the above sources.

E. 1.9 and 3.8 cm Observations

In order to investigate the nature of variable radio sources, it is necessary to have observations during roughly the same time period at as many wavelengths as possible. The 11 cm data discussed earlier in this chapter was combined with work done at the Haystack Radio Observatory at 1.9 and 3.8 cm to provide wider frequency coverage of a number of radio sources.

The description below of the Haystack observations and procedures can be found in greater detail elsewhere (Dent and Kojoian, 1972; Dent, Kapitzky, and Kojoian, 1974). The program was begun by W. Dent in 1968 and supported later by G. Kojoian and the author. Because of the experimental set-up at the 120 foot Haystack antenna, and more limited time available for a run, only a much smaller sample of radio sources could be observed in a typical 24 hour run. The number varied from a few dozen up to 60 or 70, depending upon weather conditions and equipment problems. Because of the time limitation, only flux densities were measured. At 1.9 cm a radiometer with a 2 GHz bandwidth and a system noise temperature of approximately 1000 degrees Kelvin was used. Observations were made with a 16 second integration period by a technique in which the radio source was alternated between two azimuthally aligned feeds. At 3.8 cm a paramp radiometer with 20 MHz bandwidth and system noise temperature of 150 degrees Kelvin was used. Observations were again made with a 16 second integration period, but at this wavelength only one circularly polarized feed was available. At 3.8 cm a complete measurement of a source consisted of several on-source, off-source sequences (or on-source, on-source sequences at 1.9 cm), the number depending on the strength of the source.

The major sources of error with the Haystack telescope were due to pointing and thermal effects. At 1.9 cm the

Haystack beamwidth was 2.2 arcminutes. A .25 arcminute error in pointing would result in a drop in signal strength of 3.5 per cent. Changes in the pointing by that much were observed, so it was necessary to make pointing checks on every strong source before measurement of the flux density. Sources too weak for reliable pointing checks were sandwiched in between strong sources and assumed pointing corrections used. At 3.8 cm the beam was twice as large, while the pointing errors remained the same size. So at the longer wavelength pointing was less critical by a factor of 4.

From experience it has been found that the telescope's efficiency was not only a function of elevation, but also of temperature on the dish itself. Changes in the efficiency of 12 per cent at 1.9 cm were not uncommon over a 12 hour period running from before sunrise to early afternoon. This effect was calibrated by taking frequent measurements of standard sources (DR21, 3C274, 3C123) as a means of checking on the temporal stability of the antenna efficiency.

Data reduction was a two stage process in which the observed antenna temperatures were punched on computer cards after the raw strings of on-source, off-source temperatures have been subtracted and averaged together. This punched output was next used as the input to a program that ran through the observations searching for measurements of standard objects. Using these standards as calibrators, the source antenna temperatures were converted into flux densities. Observations up to 1973.0 at 1.9 cm (Dent, Kapitzky, and Kojoian, 1974) and up to 1971.6 at 3.8 cm (Dent and Kojoian, 1972) have been published. The graphs in Chapter IV of flux density variations at several frequencies include both the published observations and data yet to be published. Editing has not been completed on the unpublished observations presented graphically.

F. 9.6 mm Observations

The 9.6 mm (31.4 GHz) observations to be presented graphically in Chapter IV were taken by William A. Dent and Robert W. Hobbs on the 36 foot millimeter wave radio telescope of the National Radio Astronomy Observatory located on Kitt Peak in Arizona. A brief summary of their observing procedure follows. More details can be found elsewhere (Dent and Hobbs, 1973).

The 31.4 GHz radiometer had a noise temperature of 1100°K and a 400 MHz bandwidth. The radiometer input was switched between two orthogonal linearly polarized horns 50 times a second. The two horns, separated in azimuth by 9' 25", were alternately pointed at the source for 30 seconds. About 20 such integrations were combined into a typical measurement. Corrections were made for atmospheric attenuation and close attention was paid both to possible antenna pointing errors and to thermal effects in the dish. Flux density calibration was relative to the galactic thermal source DR21.

Observations from 1970.0 to 1972.5 have been published (Dent and Hobbs, 1973). The observations since 1972.5 are as yet unpublished and not entirely edited. They have been made available with the kind permission of Drs. Dent and Hobbs.

CHAPTER IV

DISCUSSION

A. Flux Density Variability

As an objective criterion for whether or not a radio source showed flux density variations, a variability index was developed. It was defined as the ratio of the standard deviation about the mean flux density (averaged over all runs) to the average scatter for a run (also averaged over all runs). For a nonvariable source this ratio would ideally be 1.0, and for a variable source it would be greater than 1. However, examination of the variability index (henceforth referred to as η) for a wide selection of sources believed to be constant revealed an average η of 1.3 with a standard deviation about the mean of 0.1 and the error bar for a single point of ± 0.4. Known flux density variables showed much larger η's. The discrepancy between 1.0 and 1.3 may be due to statistical fluctuations, or it could additionally reflect an underestimation in the calculation of the errors for sources in a given run when $N < 4$. If the latter is true, then the area of underestimation is probably in the error contribution from gain changes or pointing errors. It was decided to consider a source variable if $\eta > 2.30$. For all sources, the mean quantities (averaged over all runs) $\overline{S}_{tot} \pm \Delta S_{tot}$, $\overline{m} \pm \Delta m$, $\overline{\chi} \pm \Delta \chi$, the number of points used to calculate the mean flux density and polarization properties, N_s and N_p, and η were tabulated (see Table IV-1). For sources with $\eta > 2.30$, listings of the same quantities for each run are given in Appendix I. The quantities $\overline{S}_{tot}$, $\overline{m}$, and $\overline{\chi}$ for each run were also plotted as functions of time, as were the flux density measurements made at the Haystack Observatory (7.9 and 15.5 GHz) and at Kitt Peak (31.4 GHz) for sources common to all observing programs. The graphs appear in Appendix II. Some sources with $\eta \leq 2.30$ were tabulated and graphed if measurements at higher frequencies suggested variability.

The average values shown in Table IV-1 were computed in the following manner. Values of S_{tot} for each run were averaged together in the usual way, with the error taken to be the standard deviation about the mean. To determine the average m and χ, the Q' and U' values were averaged over all runs and combined to produce mean values with their standard deviations. These were then used in equations III-25 and III-26 to calculate $\overline{m}_{observed}$ and $\overline{\chi}_{observed}$. Wardle and Kronberg (1974) have pointed out that observed degrees of polarization tend to be overestimated, because the noise adds vectorially to the polarized flux. So, for a large sample of measurements, a corrected degree of polarization can be computed:

$$\overline{m}_{corrected} = \overline{m}_{observed}[1 - (\Delta m/\overline{m}_{observed})^2]^{1/2} \tag{IV-1}$$

The error in χ becomes

$$\Delta\chi = \Delta m/(2\overline{m}_{observed}) \tag{IV-2}$$

Table IV-1

Average Flux Density and Polarization Values for Program Sources

Source	S	ΔS	m	Δm	χ	$\Delta\chi$	NS	NP	η
0001+17	.27	.00	2.9	1.0	66.4	9.4	11	10	.5
0048-09	1.70	.07	2.4	.4	88.7	5.2	12	11	4.8
0106+01	3.29	.13	1.2	.2	111.7	3.9	12	10	8.4
0119+11	.84	.03	3.0	.6	157.8	5.4	11	10	3.1
0133+47	2.03	.19	2.6	.8	6.9	8.8	11	10	19.1
NGC1052	.72	.05	1.3	1.6	84.6	22.6	12	10	5.0
3C74	.48	.00	9.3	.5	155.9	1.5	12	11	.7
CTA21	5.13	.02	.4	.1	.0	7.9	12	11	1.0
3C84	21.0	.7	0.0	.1	23.3	43.7	12	10	11.9
0333+32	3.13	.04	2.6	.2	94.4	2.3	12	11	3.4
CTA26	2.33	.12	2.5	.4	172.1	4.1	12	11	10.3
NRAO150	5.66	.05	2.5	.2	103.0	1.9	12	11	2.0
0405-12	2.37	.03	.8	.3	118.5	11.4	12	11	1.4
0420-01	1.17	.01	2.3	.2	82.5	2.8	12	11	2.1
3C120	8.73	.22	2.2	.1	173.3	1.9	12	11	7.2
0440-00	2.57	.08	1.6	.1	47.8	2.0	12	11	6.2
0458-02	1.87	.05	.9	.5	164.3	13.9	11	9	4.6
3C136.1	2.95	.01	14.6	.5	174.1	1.0	11	10	1.7
3C140	.46	.01	1.0	2.5	81.1	26.6	5	5	.4
0552+39	3.84	.03	.1	.2	89.2	25.9	12	11	3.1
0605-08	3.43	.10	.5	.2	42.7	12.3	12	11	4.2
0607-15	1.82	.08	.9	.4	59.2	11.8	12	11	4.1
0621+32	1.01	.01	2.2	.3	90.5	4.3	10	9	.7
3C161	10.97	.09	10.5	.7	177.0	2.0	11	10	1.6
0628+19	.71	.01	4.3	.2	138.4	1.3	10	9	1.3
0723-00	2.07	.07	2.8	.2	120.5	2.4	12	11	7.8
0727-11	3.07	.12	0.0	.6	154.7	31.7	12	10	6.8
0735+17	2.07	.08	2.0	.4	60.0	5.3	11	10	8.0
0736+01	1.90	.03	5.2	.2	83.4	1.2	12	10	3.0
3C188	.44	.00	9.8	.8	112.7	2.4	12	11	.7
0820+22	2.04	.01	1.7	.3	25.5	4.5	12	11	1.4
0831+55	7.54	.02	.0	.1	86.7	24.4	12	11	.9
0839+18	1.27	.01	4.1	.5	155.9	3.2	11	10	1.2

Table IV-1 (Continued)

Source	S	ΔS	m	Δm	χ	Δχ	NS	NP	η
OJ287	3.15	.14	2.4	1.3	101.5	13.7	11	10	13.9
0859-14	3.02	.04	4.3	.2	92.9	1.2	12	10	2.0
4C39.25	5.03	.03	1.4	.3	1.8	6.9	12	10	1.6
0932+02	.49	.01	5.4	1.0	159.4	5.0	12	11	1.8
M82	5.03	.05	.8	.1	16.1	2.3	12	11	2.3
0953+25	1.19	.02	1.0	.6	14.4	15.3	12	11	2.3
1010+35	.56	.01	9.8	1.0	5.2	3.0	12	11	1.8
1019+30	.75	.00	.7	.2	142.9	8.3	12	11	1.0
1055+01	2.84	.03	4.0	.1	91.7	.6	12	11	2.8
1106+37	1.23	.01	10.3	1.1	174.2	3.1	10	9	1.8
1116+12	1.70	.01	1.3	.1	124.2	3.2	11	11	1.3
1127-14	6.40	.06	1.5	.3	17.6	6.3	12	11	1.5
1215+30	.52	.01	3.2	.5	57.5	4.3	12	11	1.1
3C273	41.8	.2	2.1	.2	159.3	2.1	12	11	1.5
3C274	116.6	.7	.2	.1	17.2	13.8	11	10	1.9
3C279	12.24	.24	2.0	.2	139.8	2.9	12	11	5.1
1306-09	2.96	.01	.6	.2	100.1	9.9	11	11	.8
1317-00	.98	.02	5.6	.3	137.4	1.4	11	10	1.7
1345+12	3.84	.01	.1	.1	163.0	20.0	12	11	.6
1354-15	1.56	.05	3.6	.5	97.6	3.8	12	11	4.2
1404+28	2.01	.01	.3	.2	16.9	17.3	12	10	1.4
1421+12	.70	.00	3.4	.4	20.2	3.6	12	11	.6
1434+06	.64	.01	7.2	1.8	159.2	6.9	5	5	1.0
1442+10	1.79	.02	.8	.1	58.9	3.7	12	11	3.0
3C309.1	5.17	.08	.4	.2	85.5	11.2	12	11	2.9
1502+10	1.81	.03	2.4	.2	8.4	2.6	12	10	3.2
1510-08	2.20	.14	2.0	.4	84.3	6.0	12	11	9.2
1518+04	2.31	.01	.2	.2	159.9	17.4	12	11	1.3
1532+01	1.08	.01	1.2	.6	157.0	12.5	11	10	1.3
1535+13	1.03	.01	2.8	.3	75.8	2.9	12	11	1.9
1548+05	2.11	.05	1.5	.2	82.5	3.6	12	11	6.9
1555+00	1.38	.04	2.4	.3	100.7	3.3	12	11	6.6
1607+26	3.14	.01	0.0	.2	21.6	32.3	12	11	1.3
1611+34	2.62	.02	1.7	.3	14.8	5.3	12	11	2.1
1616+06	.95	.02	2.4	.4	92.7	4.4	12	11	3.0
1624+41	1.69	.01	.7	.8	177.3	22.3	12	11	2.4
3C345	10.28	.12	2.3	.1	60.0	1.4	11	11	3.9
1656+05	1.69	.02	3.3	.2	19.4	1.8	12	11	2.4
1708+00	.82	.01	.8	.2	126.9	5.9	12	11	.9
1722-02	1.33	.02	4.1	.2	103.0	1.6	12	11	2.7
1730-13	4.78	.10	1.7	.2	32.9	3.3	10	9	4.9

Table IV-1 (Continued)

Source	S	ΔS	m	Δm	χ	Δχ	NS	NP	η
1741-03	2.10	.10	1.8	.2	78.3	3.5	11	10	8.0
1749-09	.96	.04	1.9	1.1	81.4	14.5	12	11	8.0
3C371	2.22	.02	2.2	.2	8.7	2.2	11	10	1.6
M17	628.3	7.5	.5	.1	20.7	6.7	11	11	1.1
1819+39	1.92	.01	0.0	.3	105.5	43.7	10	10	1.4
3C380	9.53	.06	1.1	.2	10.1	4.6	11	10	2.0
3C390.3	6.75	.05	4.1	.3	30.7	1.9	12	11	1.4
1922+33	2.75	.01	1.7	.2	111.8	3.1	11	10	1.7
3C405	796.9	4.6	.3	.1	173.5	11.2	12	11	1.6
2005+40	4.00	.07	2.1	.1	113.9	.9	2	2	3.0
2008-06	2.10	.03	.3	.4	100.6	24.3	10	9	1.5
3C418	4.10	.07	2.3	.1	110.3	1.8	12	11	3.8
2050+36	4.55	.06	0.0	.2	173.2	82.8	11	11	3.4
2113+29	1.05	.03	.1	.5	6.2	28.0	12	11	4.8
2134+00	7.01	.06	.2	.1	130.8	6.8	12	11	2.5
2145+06	3.22	.03	.2	.1	87.7	8.9	12	11	2.6
BL Lac	4.90	.45	1.1	.6	109.4	14.2	12	11	29.4
2201+31	2.14	.06	.7	.1	132.3	4.1	11	10	6.3
2216-03	1.30	.02	1.0	.5	96.8	12.0	12	11	2.7
3C446	4.62	.06	5.2	.5	172.5	2.5	12	11	2.4
CTA102	4.70	.02	4.6	.2	12.4	1.1	12	11	1.6
2243-12	2.51	.03	3.7	.6	175.0	5.0	11	10	2.5
3C454.3	10.67	.08	6.0	.2	168.4	.9	12	11	3.4
2335+03	.93	.01	1.1	.5	94.5	13.0	11	11	1.3
2345-16	3.95	.10	0.0	.4	79.1	49.5	12	10	3.9
2354-11	1.57	.02	0.0	.5	164.8	70.4	12	11	1.3

Key

S, ΔS -- Flux Density (Janskys)

m, Δm -- Degree of Polarization (%)

χ, Δχ -- Position Angle (Degrees)

The corrected degree of polarization appears in Table IV-1.

B. Possible Variable Standards

Data for the standard sources whose variability indices (η's) were greater than 2.30 have been plotted in Appendix III, along with a tabulation of the data. η was greater than 3.0 for only three of the eight suspects: 1150+49, 3C395, and 2209+08. For the five with $\eta \leq 3$, only 3C433 (η = 2.7) and 3C78 (η = 2.5) appeared variable when graphed. The removal of one point would have reduced η_{3C78} to 2.0 and made its graphed appearance look constant. On the other hand, 3C433's variations look real. This is peculiar in that most variable sources have spectral indices greater than or equal to -.5 (Kellerman, 1974), whereas the index for 3C433 has been computed to be -.88 and that of 3C78 to be -.54 (Kellerman et al., 1969). Of the two objects, 3C78 would have seemed the more likely candidate for variability.

Of the three objects with η greater than 3.0, both 1150+49 and 2209+08 showed evidence of .2 to .1 Jansky decreases in flux density in 1974 and 1975. No spectral indices were available. In the case of 3C395 the removal of one point would have reduced η to 2.1. But the measurement at 11 cm by Kellerman, Pauliny-Toth, and Tyler (1968) on which the original standard value was based was ~20% below the final adjusted value, in comparison to 2% to 3% adjustments for other KPT measured sources used as standards.

This suggests a large variation since the late 1960's and makes this source worth watching in the future.

Although relatively constant in flux density, the polarization standard 3C161 is interesting because of an apparent change in the degree of polarization in mid-1973. With a standard value for m of 10.5%, the peak value measured was almost 16%. The run near the time of the polarization peak was reprocessed without 3C161 as a standard in order to determine if that run's calibration had been affected, and it was found that it had not been. The fact that several other sources (not standards) at similar declinations have shown the same behavior has been noted earlier. Rather than the activity of 3C161 affecting the calibration and producing similar variations in the other sources mentioned earlier, it seems more likely that the cause (if more than just an unfortunate coincidence) has affected both standards and unknowns alike.

In summary, then, five standard sources (1150+49, 3C395, 3C433, 2209+08, and 3C161) showed evidence of variations. Although their changes have been fairly small (with the exceptions of 3C433 and 3C161) and have not affected the various runs' calibrations, they should be removed as future standards. These sources should be watched for further evidence of variations.

C. New Variable Sources

Using the parameter η described earlier in this chapter as a criterion for variability, nine new objects (in addition to the variable standards discussed in the previous section) were found to be potential variable sources at 11 cm. They are listed below in Table IV-2.

Table IV-2

Potential Variable Sources

Source	η
0119+11	3.1
1442+10 (OQ172)	3.0
1616+06	3.0
1624+41 (4C41.32	2.4
1722-02	2.7
1741-03	8.0
1749+09 (OT081)	8.0
2050+36 (DA529)	3.4
2113+29	4.8

Examination of these objects' graphed variations revealed that most of the above sources were marginal variables at 11 cm. Only 1741-03, 1749+09, and 2050+36 showed strong systematic changes in total flux. Nevertheless, continued observations should be made of all objects in the above list until such time as the marginal variables can be reclassified as either definitely variable or constant. At the same time, observations should be extended to higher frequencies, where stronger variations might be found.

D. Search for Daily Variations

Observations have been made in the past pointing to the possibility that some radio sources variable on timescales of months or more also vary with timescales of days (Wills, 1971). To further examine the possibility of such variations at 11 cm, the daily observations of sources likely to show such variations have been analyzed. The rapid variables 0J287 and BL Lac were included in this study, in addition to the four sources Wills found to be daily variables (0106+01, CTA26, 0440-00, and 1510-08). The procedure was to compare the difference between a day's measurement of total flux for a source and the mean value for the given run against the expected error for a point, as calculated from equation III-28. In no case was the difference more than twice the calculated error. Thus, to the accuracy of the flux density measurements in this program, as discussed in Chapter III, no evidence was found for day to day variations in the above sources.

E. General Remarks

The 2.7 GHz flux density and polarization variations of some of the sources will be examined in the following sections with respect to the expanding source model. But first the observable characteristics of the model will be reiterated.

1) An outburst that reaches a maximum at some wavelength λ_1 should reach a maximum at a later time at a longer wavelength λ_2 ($\lambda_2 > \lambda_1$).
2) The outburst duration increases, but its amplitude decreases with increasing wavelength.
3) Polarization changes occur more rapidly than flux density changes, and only around the time when total flux is a maximum.
4) The polarization position angle changes rapidly by 90 degrees just prior to the time of maximum flux density.

No one object clearly demonstrated all of the theoretical characteristics of the expanding source model. Some variables showed the expected time lag in outbursts and decrease in amplitude at longer wavelengths, yet showed little sign of polarization changes. Others varied in polarization with little changes in flux density. This lack of total agreement with the expanding source model is undoubtedly a manifestation of the more complicated nature of the actual sources. Prolonged injection of electrons, multiple outbursts at different locations in space, and variations in magnetic field through the source modify the basic model.

A continuing difficulty of making numerical comparisons of observations with the theory has been determination of a base level of constant total flux and polarization. Because variable sources generally have not been observed to decrease to zero flux density during quiescent periods, it is probable that the measured flux densities are the sum of a constant term and a variable contribution. For sources like 0048-09, 1502+10, and 3C454.3, only reasonable uncertainties are involved in determining the base levels, since such sources exhibit somewhat defined quiet periods. Other sources (e.g., NGC1052 and 0440-00), which show a steady increase or decrease in flux density are not susceptible to detailed numerical analysis, because their base levels cannot be determined from present observations. Even rapid variables (e.g., OJ287, 3C120; 1510-08, and BL Lac), which show several outbursts are difficult to analyze because of the uncertainty of how much the outbursts overlap. As a result, in the following discussion of sources, only the qualitative aspects of the expanding source model will be looked at, unless there are expectations of deriving reasonable numbers.

The sources have been crudely categorized into three groups in Table IV-3: 1) those which are constant in flux density and variable in polarization (SC/PV), 2) those which are variable in flux density and constant in polarization (SV/PC), and 3) those which are variable in both flux density and polarization (SV/PV). The division between SV/PC and SV/PV sources is admittedly subjective and was mainly

Table IV-3

Source Categorization

Key	
( )	marginal flux density variations
[ ]	marginal polarization variations
*	no polarization data available
SC/PV	flux density constant and polarization variable
SV/PC	flux density variable and polarization constant
SV/PV	flux density and polarization variable

SC/PV	SV/PC	SV/PV
1722-02	0106+01	0048-09
3C161	(0119+11*)	0133+47
	NGC1052*	[0333+32]
	(CTA21)	[CTA26]
	3C84	[0440-00]
	NRAO150	0458-02
	0405-12	[0552+39]
	0420-01	0605-08
	3C120	0607-15
	0831+55	0723-00
	0859-14	0727-11
	M82	[0735+17]
	1055+01	[0736+01]
	(1215+30*)	OJ287
	(1345+12)	4C39.25
	1502+10	0953+25
	(1616+06*)	1127-14
	(1624+41)	[3C273]
	3C345	[3C279]
	1730-13	1354-15
	1749+09	[1404+28]
	3C371	[(1442+10)]
	3C380	[3C309.1]
	3C390.3	1510-08
	3C418	[1548+05]
	2050+36	[1555+00]
	2113+29	[(1607+26)]
	2134+00	[(1611+34)]
	2145+06	[1656+05]
	2201+31	1722-02
	2345-16	[1741-03
	(0256+07*)	BL Lac
	(3C78)	2216-03
	(0906+01)	3C446
	3C287	[CTA102]
	(3C395)	2243-12
	3C433	3C454.3
	2209+08	[1150+49]

based on the degree and magnitude of scatter of points about average polarization values. The categorization is only intended as a rough guide for later reference.

F. Time Delayed Outbursts

One of the predictions of the simple expanding source model is that the maximum flux density during an outburst occurs at later times at lower frequencies. If the source is transparent to radiation throughout the event, then the peak flux density should occur at the same time at all transparent frequencies. Of the variable sources in this program that have been monitored at several frequencies, a few more than ten have shown definite peaks since the beginning of the 11 cm program. Examination of these sources revealed that a combination of both types of behavior was common.

Table IV-4 lists those sources which have shown discrete or overlapping events since 1971.0. The sources are divided into three groups: 1) sources showing delays from frequency to frequency in the time of peak flux density for an event (TD), 2) sources in which events occurred simultaneously at all frequencies (TS), and 3) sources showing events of both of the above two types (TS/TD). For those sources in which the events are sufficiently well-defined, Table IV-5 presents details about the timing of the outbursts.

Bearing in mind that the 31.4 GHz observations were too

Table IV-4

Categorization of Sources
with Time Delayed Outbursts

TD	TS	TD/TS
0106+01	0048-09	3C120
0133+47	NRAO150	3C454.3
3C84	0735+17	
0458-02	OJ287	
0605-08	1502+10	
0607-15	1510-08	
3C273		

Key

TD	Time delayed outbursts
TS	Simultaneous outbursts
TD/TS	Combination of TD and TS

Table IV-5

Data on Time Lags in Sources

Source	Time of 15.5 GHz Outburst Peak	Frequencies of Simultaneous Peaks (GHz)	Frequencies of Delayed Peaks (GHz)
0048-09	1972.9	15.5, 7.9, 2.7	
	1974.6	15.5, 7.9, 2.7	
0106+01	1973.3	15.5, 7.9	7.9 to 2.7
0133+47	1974.2	31.4, 15.5, 7.9	7.9 to 2.7
3C84	1973.5	31.4, 15.5	15.5 to 2.7[1]
NRAO150	1973.9	31.4, 15.5	[2]
3C120	1973.0[3]	31.4, 15.5, 7.9	7.9 to 2.7
	1975.3	15.5, 7.9, 2.7	
0735+17	1975.1	31.4, 15.5, 7.9	(7.9 to 2.7)[4]
3C273	1973.6	31.4, 15.5	15.5 to 2.7
	1975.5		31.4 to 2.7
1502+10	1973.2	15.5, 7.9	(7.9 to 2.7)[4]
1510-08	1974.0[3]	15.5, 7.9, 2.7	
3C454.3	1972.2	31.4, 15.5, 7.9	
	1974.4		31.4 to 2.7

Notes

1) The peak has not yet been reached at 7.9 or 2.7 GHz.
2) The event does not exist at or below 7.9 GHz.
3) This is really two overlapping events.
4) This was probably simultaneous. The 2.7 GHz data is inconclusive.

sparse in several cases to be sure of having defined the peaks adequately, the source outbursts generally seem to have been transparent down to some frequency within the observed spectral region, below which the events were time delayed. The transition frequency was often between 15.5 and 7.9 GHz. In only a few cases were outbursts transparent (3C120 at 1975.3) or time delayed (3C454.3 at 1974.4) at all observed frequencies. Sources with more than one outburst exhibited a non-uniformity of behavior. 3C120 had one totally and one partially transparent event, and 3C273 showed both a partially transparent event and one in which opacity effects were important at all frequencies. The similarity of the transition frequency in many of the events suggests a uniformity or at least a narrow spread in some of the initial conditions determining the outbursts.

The behavior of a few of the sources listed in Tables IV-4 and IV-5 reveals that dispersion through the intergalactic medium can be ruled out as the cause of the time delayed outbursts in at least some of the sources. Dispersion within our own galaxy affects the arrival times of pulsar signals. It results from the presence of free electrons along the line of sight between a source of radio emission and an observer. For radio waves propagating through such an ionic medium, the group velocity is less than the speed of light, and in fact is inversely proportional to the square of the frequency. Thus, a burst of radio energy emitted simultaneously at all wavelengths passing through such a medium would arrive first at higher frequencies and later at longer wavelengths. The time delayed nature of the outbursts noted in several sources could thus be interpreted as being due to dispersion rather than to opacity effects within an expanding source.

If the 1974-75 outburst in 3C454.3 was delayed at longer wavelengths because of dispersion through the intergalactic medium, then the measured delay in arrival time between the 31.4 GHz and 2.7 GHz peaks can be used to compute the necessary intergalactic electron density. With a time delay of 1.3 years between the peaks in flux density at 31.4 GHz and 2.7 GHz, a dispersion constant DC can be calculated according to the formula (Manchester, 1974):

$$DC = \Delta t/[1/\nu_1^2 - 1/\nu_2^2]$$

where Δt is the time delay

ν_1, ν_2 are the frequencies of the measured peaks ($\nu_1 < \nu_2$)

The resulting value is 3.0×10^{26} sec^{-1}. The dispersion constant DC is related to the electron density n_e along the line of sight l by the equation (Manchester, 1974):

$$\int_{\text{line of sight}} n_e \, dl = 2.41 \times 10^{-16} \, DC$$

where n_e is in cm^{-3}

dl is in parsecs

If a uniform intergalactic medium is assumed, then $\int n_e \, dl \approx$

$n_e D$, where D is the distance to the source. For 3C454.3, which has a z of .86 (Hunstead, 1972), D = 2.7×10^9 pc (assuming $q_o = 1/2$). Thus, since

$$n_e D = 7.2 \times 10^{10} \text{ pc cm}^{-3},$$

the electron density is 27 cm^{-3}, or 2.5×10^{-26} gm/cm^3. This density for the intergalactic medium is considerably greater than that necessary to close the universe ($\approx 10^{-29}$ gm/cm^3).

However, the behavior of 3C120 and 3C454.3 have reduced the likelihood of a dispersion origin. In each of these two sources, there have been two events, one reflecting simultaneous outbursts at all frequencies and the other showing time delays. One would expect all outbursts for a given source to be equally dispersed, if the bulk of dispersion were due to the intergalactic medium, and this has not been the case for these two objects. Unfortunately, the data for the 'simultaneous' event does not have sufficient time resolution to permit a precise estimate of the upper limit on the intergalactic electron density.

G. Polarization Variations

About 50 percent of the sources showing flux density variations also showed evidence of polarization variations. A number of these polarization variations were of the form predicted by Aller; that is, the position angle changed by roughly 90 degrees around the time of peak flux density during an outburst, in addition to a change in the degree of polarization. Sources in this category included 0133+47, 0605-08, 0607-15, 0727-11, OJ287, and BL Lac. The first three objects also exhibited evidence of time delayed outbursts in total flux. The time delay behavior reinforces the belief that the polarization changes in these objects were an opacity effect, since the large opacities necessary to delay an outburst at 2.7 GHz would also have resulted in well-defined changes in the polarization angle as the larger opacities decreased. In a few of the sources (BL Lac, OJ287), however, there was little, if any, time delay in the flux density events despite large changes in χ, suggesting that the polarization variations in these sources may have had another cause. In any case, the relatively low frequency of 2.7 GHz with the larger associated opacities in the expanding source model make this a good frequency for the examination of polarization variations expected from the model.

Most of the sources, both variable and constant, possessed degrees of polarization much lower than expected in an isolated expanding source. As has been suggested elsewhere, this can probably be interpreted as resulting from a low degree of order in magnetic field orientation within many of the sources. This is further supported by the paucity of sources showing well-defined 90 degree rotations in polarization position angle, despite possessing time delayed outbursts in total flux (3C454.3, for example).

Several sources have shown polarization variations much more gradual than those predicted by the expanding source model. Either m or χ or both vary by no more than a few percent or a few tens of degrees over the course of a year or more. Examples include 0048-09, 1442+10, and 3C446.

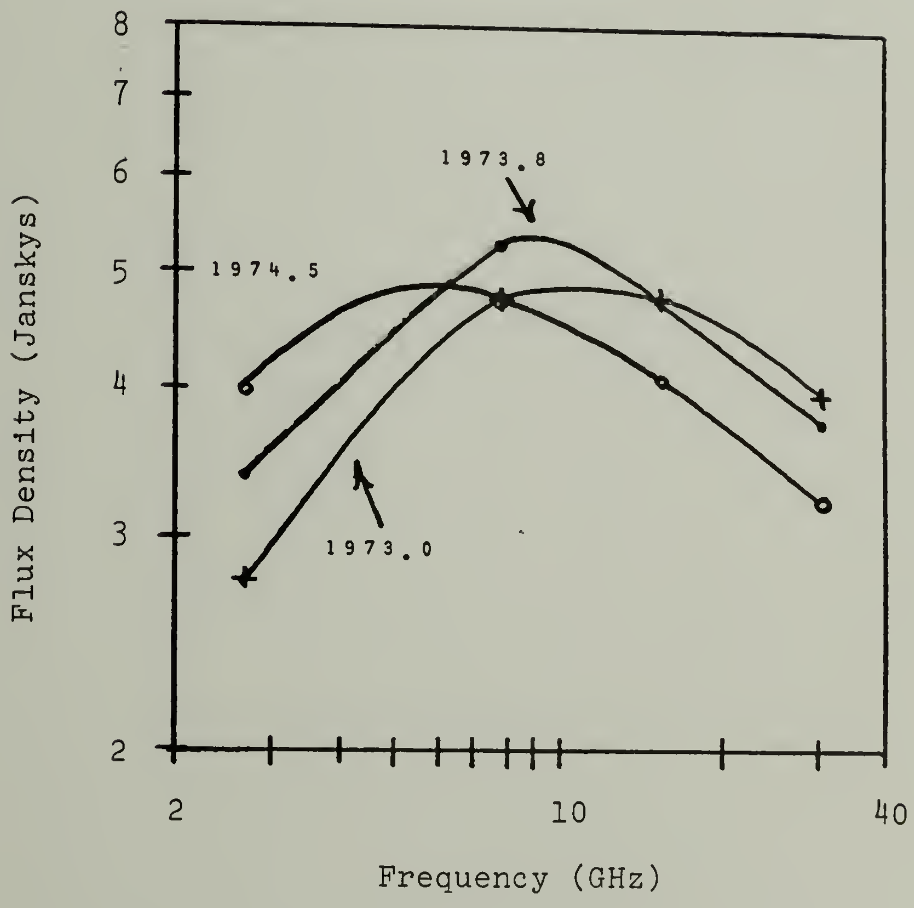
The source 3C161 is interesting, because of a large flare-up in the degree of polarization in the middle of 1973. There was no comparable change in total flux at the same time. The source 1722-02 also showed evidence of polarization variations despite constant total flux. Similar behavior in other sources at 2.8 and 4.5 cm has been noted by Bignell and Seaquist (1973). They found that 2134+00, 3C454.3 and several other objects showed variations in polarization during times when their flux densities were not changing.

H. Discussion of Several Sources

As an example of a relatively uncomplicated expanding source, consider 0106+01. An outburst that peaked at 15.5 GHz around 1973.3 was delayed until 1974.5 in reaching its maximum at 2.7 GHz. Figure IV-1 shows the source's spectrum at several epochs during the outburst. The general qualitative behavior was what one would expect from the van der Laan model. Early in the outburst, the high opacity at lower frequencies produced a maximum in the spectral curve above 10 GHz. As the source expanded and the opacity

Figure IV-1

Spectrum of 0106+01 at Several Epochs



dropped at lower frequencies, the maximum moved to lower frequencies. The spectral indices at the three epochs in the transparent part of the spectrum were around -.3, suggesting a value for γ of ~1.6. (Recall that γ defines the energy spectrum of the electrons that are injected according to the number density relation $N(E)dE \propto E^{-\gamma}$, where E is the energy of the particles.)

It should be noted that no effort was made to remove a possible constant component of the flux density at each frequency, because of the lack of information on the source's quiescent radio emission. If the constant component has a spectral index less than zero, as was likely (Kellerman et al., 1969), then the transparent region spectral index of the variable component was less negative and $\gamma < 1.6$.

During the outburst 0106+01's behavior did deviate from the instantaneous injection form of the model. Equation II-12 predicts that the peak flux density at 7.9 GHz should have been 3.4 times that at 2.7 GHz, assuming that $\gamma \sim 1.5$. The amplitude of the outburst at 2.7 GHz was at least 1.5 Jansky, indicating that the amplitude at 7.9 GHz should have been greater than 5.1 Jy, yet it was probably only around 3 Jy.

The observations suggest that a prolonged injection of electrons took place (Peterson and Dent, 1973). The similarity in times of maximum flux density at frequencies above 7.9 GHz can be interpreted as reflecting the transparent nature of the event in this spectral region. At these frequencies (ν > 7.9 GHz) the increase and decrease in flux density are directly related to the number of relativistic electrons emitting radiation. But below 7.9 GHz the marked delay in times of peak flux density is due to opacity effects finally becoming important.

Taking the calculated value for γ of 1.6, the change in the degree of polarization to be expected during the outburst can be computed from Aller's extension of the model. His theory predicts a degree of polarization before the peak in flux density of 13 percent and afterwards of 66 percent (assuming an instantaneous injection of electrons and a homogenous magnetic field through the source). Assuming the model fits at 2.7 GHz, and taking the amplitude of the outburst as 1.5 Jy, and the size of a constant component of total flux to be 2.5 Jy, then one would have expected observed polarizations before and after the peak of ~5 percent and ~27 percent, respectively. There should also have been a rapid 90 degree change in position angle around 1974.5. That the observed polarization was remarkably constant around mean values of $\bar{m}$ = 1.2 percent and $\bar{\chi}$ = 113 degrees suggests that the ordering of the magnetic fields within the source was quite poor.

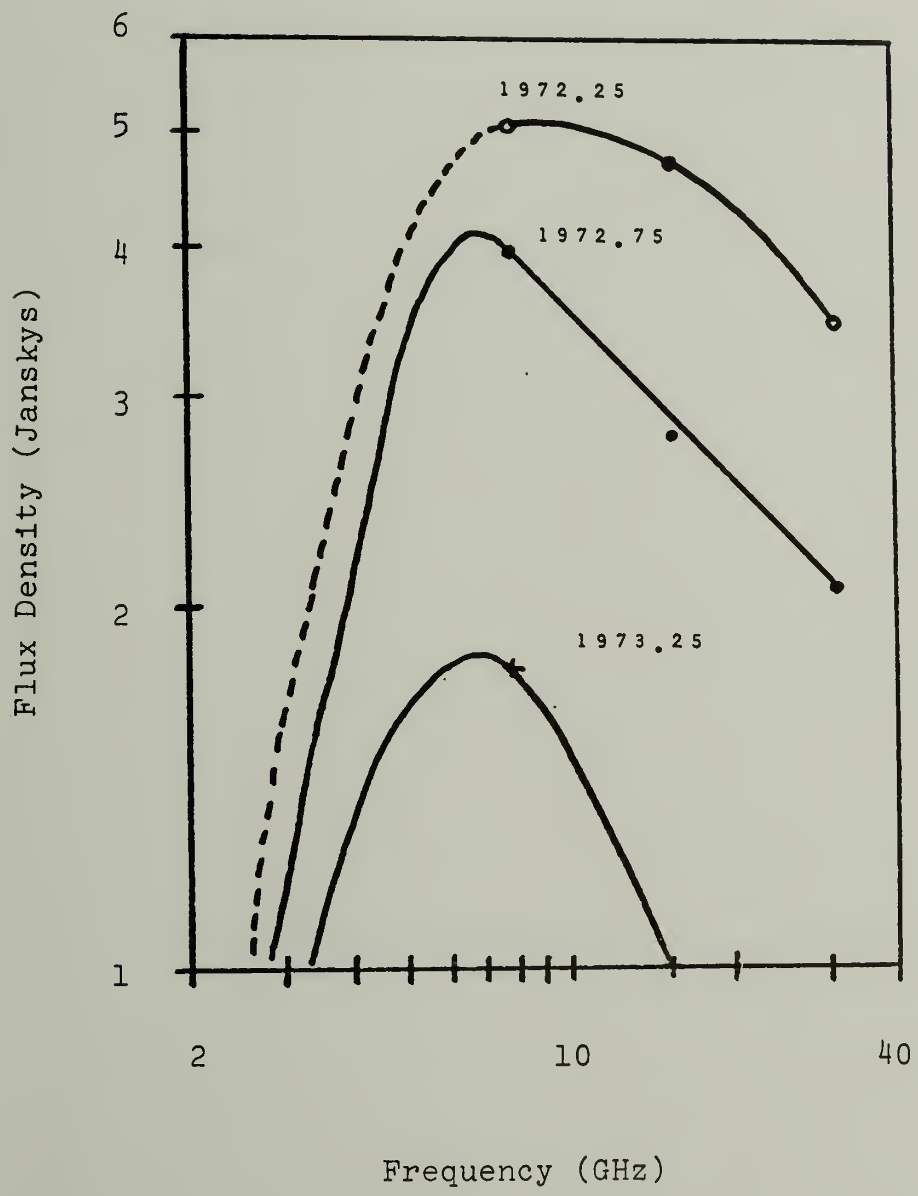
A more complicated and more interesting source for examination is 3C454.3. Associated with a 17 magnitude QSO with a redshift of .859 (Hunstead, 1972), 6 cm VLBI observations (Kellerman et al., 1971) have shown two components of sizes ~0"002 and ≤ 0"0004. The source has varied in total flux at frequencies from 408 MHz through 31.4 GHz with well-defined outbursts above 2.7 GHz.

The outbursts since 1971.0 illustrate two kinds of behavior. The event that began around 1971.4 developed simultaneously at 7.9, 15.5, and 31.4 GHz, with evidence of little variation at 2.7 GHz (the 2.7 GHz data is incomplete for the event, however). The peak flux density for the event decreased with increasing frequency (for ν > 7.9 GHz), suggestive of the expected spectral index (α < 0 when γ > 1) for a source in which particle injection was too low for synchrotron self-absorption to be important at ν > 7.9 GHz. As the spectral curve dropped to lower flux densities during the decreasing phase of the outburst, the spectrum shape and frequency of maximum flux density changed little (see Figure IV-2).

The second outburst, beginning in the latter half of 1973, followed van der Laan's original model in two regards. First, there was a time delay between the peaks at successively lower frequencies. Secondly, the amplitude was greater at higher frequencies (ν < 15.5 GHz), although not as much greater as the theory predicts, assuming that the minima in the flux density curves were at least representative of the constant components. Figure IV-3 shows the spectrum of the outburst (constant component subtracted) at several epochs.

Figure IV-2

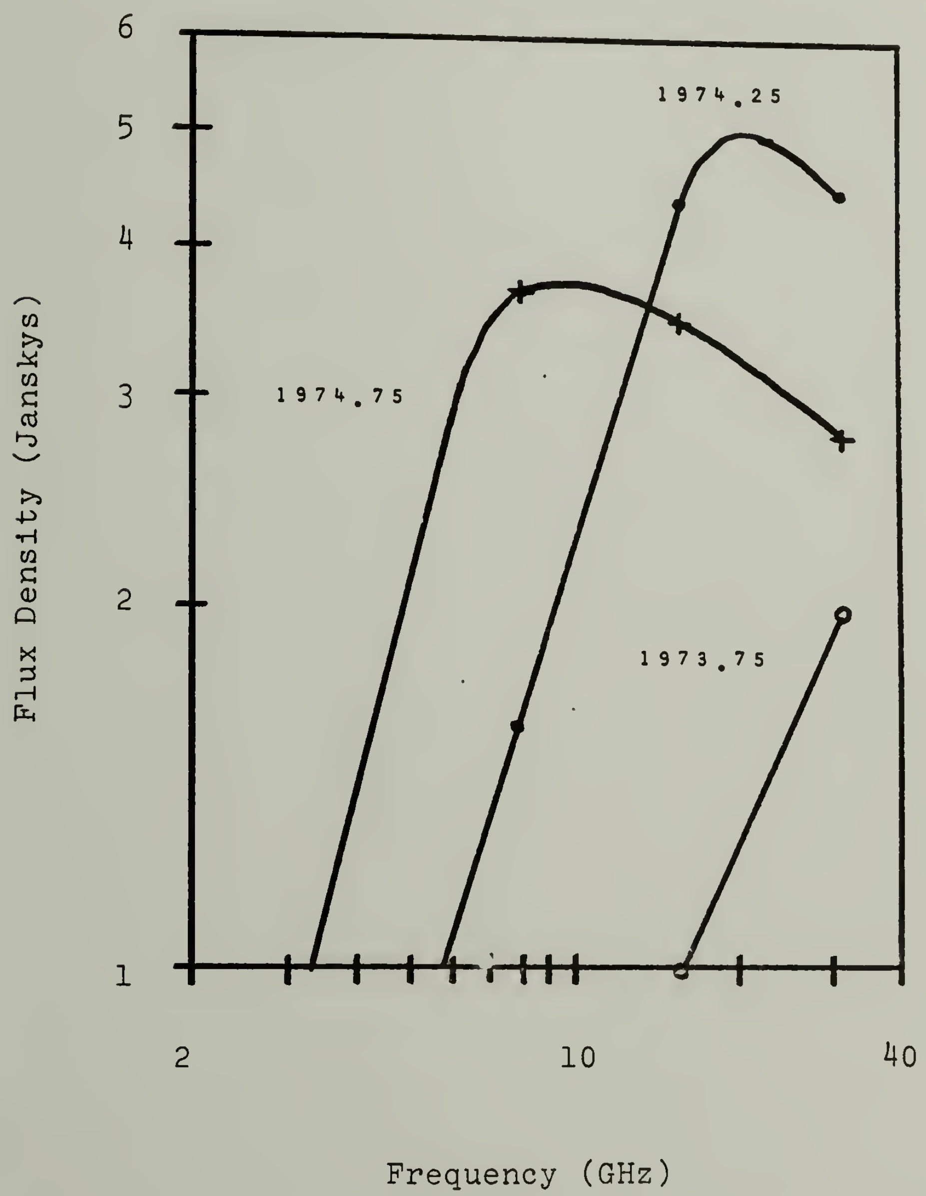
Spectrum of 3C454.3 at Several Epochs During 1972 Outburst



[Note: A constant flux density component has been subtracted.]

Figure IV-3

Spectrum of 3C454.3 at Several Epochs During 1974 Outburst



[Note: A constant flux density component has been subtracted.]

More active than 3C454.3 is OJ287, a radio source associated with a faint star-like object at galactic longitude 40 degrees. Whereas 3C454.3 showed well-defined outbursts with timescales of more than a year, OJ287's eruptions have durations of much less than a year and overlap so as to make resolution of events very difficult. Examination of the flux density activity at several frequencies indicates that there is little in the way of time delays at shorter wavelengths. Between 7.9 and 31.4 GHz, events were delayed by no more than a few tenths of a year, suggesting that the events tended to be transparent, or else that the expansion velocities were quite large. Amplitudes of events seemed larger at 15.5 GHz than at 7.9 or 2.7 GHz, agreeing at least in principle with the expanding source model.

There was a large change in the 2.7 GHz polarization beginning near the end of 1973. The degree of polarization rose from 2 percent (1973.75) up to a measured maximum of ~11 percent (1974.9) and then began decreasing. Coincident with the increase in m was a ~110 degree rotation in χ. A large change in χ and the beginning of an increase in m were also recorded for this source at 5 GHz by Seielstad and Berge (1975) (see Figure IV-4 and Table IV-6). The 5 GHz change in position angle occurred more rapidly than did the change at 2.7 GHz. Although both changes were around 70 degrees, near the prediction of Aller's model, the observations deviated from his theory in other respects. For

Figure IV-4

Flux Density and Polarization Variations in OJ287

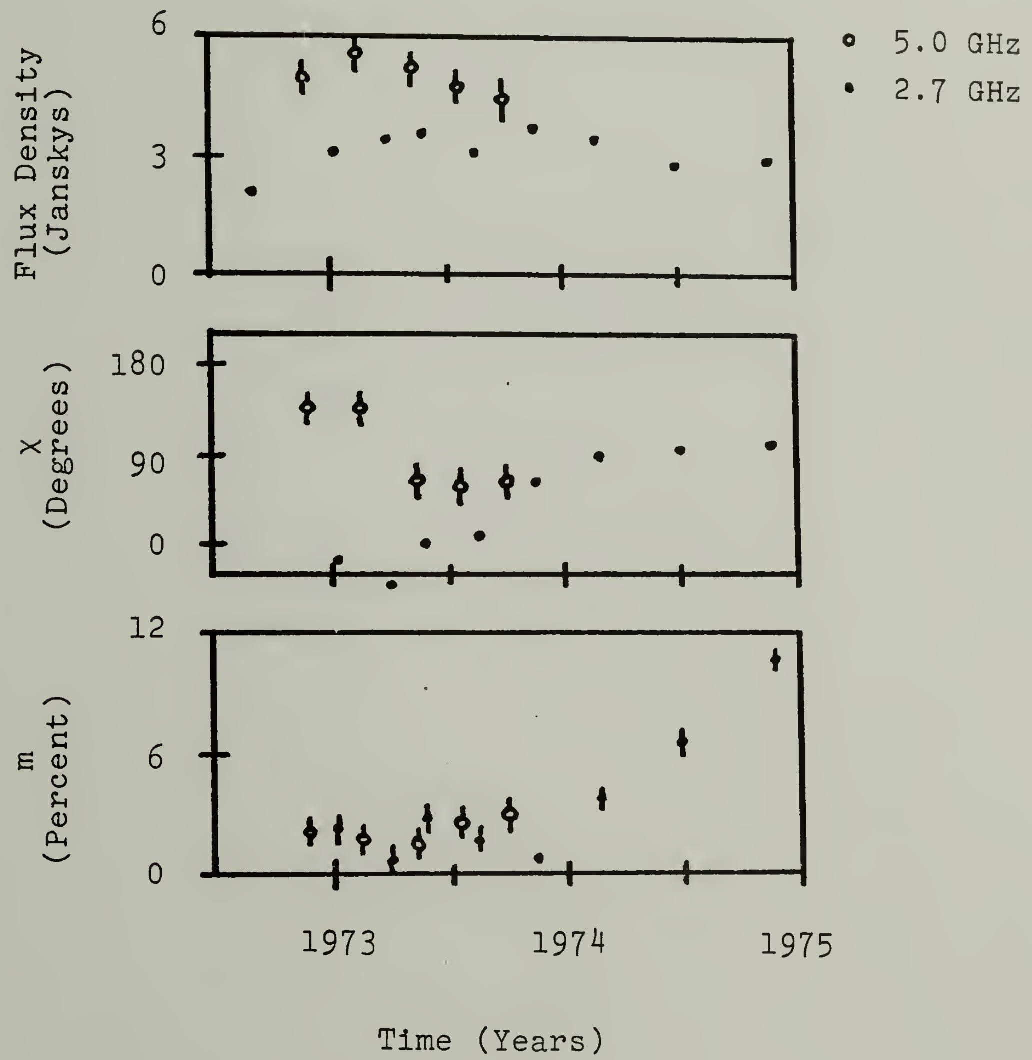


Table IV-6

OJ287 Flux Density and Polarization Measurements at 2.7 and 5.0 GHz

2.7 GHz (This study)

Date	S (Jy)	ΔS	χ (degrees)	Δχ	m (%)	Δm
1972.67	2.17	.03				
1973.04	3.13	.01	166.1	3.3	2.5	.4
1973.26	3.48	.02	141.0	5.5	.9	.2
1973.40	3.58	.08	3.5	1.1	3.0	.3
1973.63	3.16	.01	10.9	2.9	1.8	.4
1973.88	3.80	.03	66.3	4.5	.9	.1
1974.16	3.53	.03	92.5	.7	3.9	.2
1974.49	2.84	.03	96.8	1.0	6.7	.5
1974.90	2.99	.02	101.4	.7	10.8	.4

5.0 GHz (Seielstad and Berge, 1975)

Date	S (Jy)	ΔS	χ (degrees)	Δχ	m (%)	Δm
1972.89	5.02	5%	140.3	4.1	2.29	.33
1973.13	5.63	10%	138.3	3.1	2.06	.22
1973.36	5.32	5%	65.2	4.7	1.72	.28
1973.55	4.84	5%	62.6	2.6	2.69	.25
1973.74	4.50	5%	67.7	3.5	3.15	.38

example, the 5 GHz change in position angle, although coinciding with the maximum in the flux density outburst, was not accompanied by a significant change in the degree of polarization. At 2.7 GHz large changes in m and χ did occur around the same time. However, it is not clear with which of two overlapping flux density outbursts the polarization changes were associated. If associated with the first event, then it is unclear why there was a large time lag between flux outburst and polarization changes at 2.7 GHz, but not at 5 GHz. If the 2.7 GHz changes were related to the second event, then the question arises of why the 5 GHz polarization changes did not have corresponding 2.7 GHz changes. Aller's model by itself seems to be inadequate in explaining the observed polarization at two close frequencies.

I. Comments on Individual Sources

0048-09 There have been two major outbursts since 1972.5 that correlated from 2.7 GHz to 31.4 GHz, although the time resolution at 31.4 GHz was not sufficient to define outbursts exactly. Both events occurred slightly later at longer wavelengths. The 1973.0 event showed an amplitude 3 times larger at 15.5 GHz than at 31.4 GHz. The 1974.8 event was quite broad and of comparable amplitudes above 2.7 GHz. There was an increase in m during the 1974.8 event.

0106+01 One broad (greater than 2 years duration) outburst in flux density since 1971.0 for which opacity effects became important below 7.9 GHz. There was little evidence of polarization variations.

0119+11 This source was too weak for monitoring polarization. It is only a marginal flux density variable, with $\eta = 3.1$.

0133+47 The main feature of this source was an outburst starting in 1973.5 that progressed almost simultaneously at 31.4, 15.5, and 7.9 GHz, and was delayed by .5 year at 2.7 GHz. Changes in m of 1.5% and in χ of 80 degrees took place around the time of maximum flux density at 2.7 GHz. Bignell and Seaquist (1973) recorded similar slow (.5 year) 90 degree rotations in χ with no clear changes in m around the times of outbursts in total flux (mid 1968 and mid 1970) at 2.8 and 4.5 cm. The repeated well-defined changes in χ indicate a high degree of order in the magnetic fields associated with this object. The magnitude and timing of the 2.7 GHz change in χ supports Aller's predictions about polarization changes in the expanding source model.

NGC1052 A monotonic increase in flux density at 2.7 GHz followed similar changes at higher frequencies.

CTA21 This source showed little activity and possesses a low average degree of polarization (.4±.1%). The apparent changes in χ were most likely due to noise fluctuations. The computed spectral index is -1.2. Most variable sources have spectral indices $\geq -.5$.

3C84 This virtually unpolarized source has been increasing in flux density since before 1971.0 and may have turned over at and above 7.9 GHz. It is still increasing at 2.7 GHz. The spectra (see Figure IV-5) at the 1973.0 and 1975.5 epochs are remarkably similar.

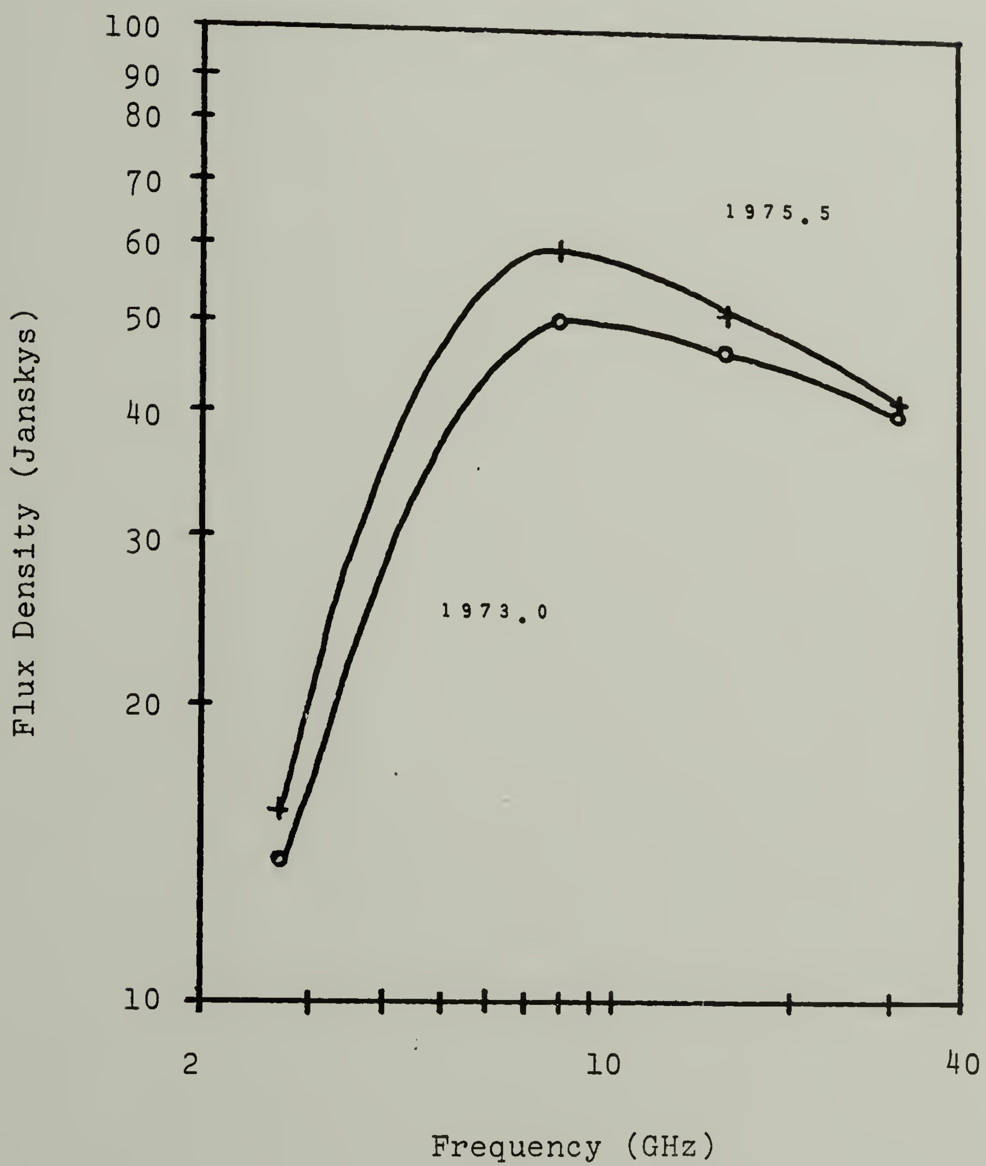
0333+32 There has been a possible slight increase in the degree of polarization from 1973.0 to 1975.5. Total flux at 2.7 GHz has been relatively constant. At higher frequencies there has been a long term decrease.

CTA26 Total flux has generally been decreasing since early 1972, although there is evidence of an upward swing after 1975.0 at frequencies above 2.7 GHz. Polarization position angle has remained essentially constant, although the degree of polarization has risen 3% since early 1973.

NRAO150 Particularly interesting was the large decrease in amplitude of the principle event from 6 Janskys at 31.4 GHz to virtually no sign of activity at 2.7 GHz. The 2.7 GHz polarization remained constant, with the possible exception of a slight rise in m

Figure IV-5

Spectrum of 3C84 at 2 Epochs



about .4 year after the peak in the 31.4 GHz outburst.

0405-12 With the exception of one point in mid-1973, polarization appears to have been constant. That data point was based on one day's observation and is suspect. Total flux shows little variation.

0420-01 Very little activity.

3C120 There were two large outbursts in total flux at 2.7 GHz. The two flux density events showed good correlation with the higher frequency observations. The burst in late 1972, early 1973 had a double peak at 15.5 GHz, but not at 31.4 GHz. There was a definite time delay in the early 1973 event that was not present in the early 1975 outburst. This demonstrates a lack of uniformity in behavior that is seen in other sources. The constancy of the polarization is in keeping with the observations of Bignell and Seaquist (1973), who observed large changes in χ and m during outbursts in 1970 at 2.8 cm, but much smaller changes in m at 4.5 cm.

0440-00 There were suggestions of slight drifts in the polarization over a 2.5 year period. Total flux has generally been decreasing, although there appear to have been small outbursts superimposed.

0458-02 There have been two possible outbursts in the degree of polarization uncorrelated with the minor changes in total flux at 2.7 GHz. At higher frequencies there may have been two highly overlapping events in 1972-1973.

0552+39 There have been only slight decreases in flux density for this source over the past two years, and it currently appears to be quiet. The combination of low degree of polarization and noise were probably responsible for the variations in χ.

0605-08 This source has had one outburst since 1971 with broad maxima at all frequencies. Three facts are interesting. First, the outburst was roughly simultaneous at frequencies at and above 7.9 GHz, suggesting transparency at wavelengths less than 4 cm. Second, while the outburst had approximately the same time scales at 7.9 and 15.5 GHz, the duration at 2.7 GHz was somewhat less. The 1975 2.7 GHz total flux levelled off only shortly after the higher frequencies, even though it probably began rising a full year and a half after the higher frequencies did. If, on the other hand, the 1972.67 2.7 GHz data point does not represent the base level prior to the outburst, and at that point the source was already increasing, then as interesting change in base levels has occurred, or else a new event is beginning that is only slightly suggested by behavior above 2.7 GHz. Third, around the time of maximum flux density, there was a 65 degree rotation in position angle and a change in m of $\lesssim$ 1%. This is another case in which Aller's prediction of a large change in position angle around the time of peak flux density in an event is borne out.

0607-15 Flux density behavior suggests several events overlapping in time. This is supported by several changes in the polarization during the same time period.

0723-00 Changes in m and χ occurred ~.5 year after the 2.7 GHz flux density reached a maximum.

0727-11 An outburst near 1974.0 was immediately preceded by a drop in the degree of polarization and a 75 degree change in position angle.

0735+17 One slow outburst since 1973.0 seems to have been almost simultaneous from 31.4 GHz down through 2.7 GHz. A possible outburst in m around 1975.5 should be viewed cautiously, since it is based on one day's observation.

0736+01 Several small outbursts superimposed on a constant background level. There is a slight suggestion of a decrease in m after 1975.0.

0831+55 This source showed virtually no flux density variation and is almost unpolarized. The variations in χ are a result of noise.

OJ287 There was a large change in m and ~90 degree change in position angle around the time of an outburst in total flux--another example in agreement with Aller's model. The flux density variations are complex and suggest several overlapping events.

0859-14 This source has shown little activity in flux density and polarization.

4C39.25 Flux density variations at and above 7.9 GHz were not seen at 2.7 GHz. The degree of polarization has varied in almost sinusoidal fashion.

M82 A quiet source.

0953+25 Flux density variations for this source have been relatively small. However, both m and χ changed significantly in 1975, during the period when toal flux seemed to be increasing slightly.

1055+01 Little activity.

1127-14 Polarization has varied more rapidly than total flux in this source. There were two outbursts in m, the second one coinciding with variation in χ.

1215+30 This source has shown only marginal variations in total flux.

3C273 This active source has had several overlapping outbursts since 1971.0, all of which have shown evidence of being time delayed at 7.9 GHz. The amplitudes of the events were much smaller at 2.7 GHz than at higher frequencies, and there has been little change in polarization during the period of observation.

3C279 The slow change in total flux at 2.7 GHz has been accompanied by slow changes in m and χ.

1345+12 Little sign of activity.

1354-15 As total flux decreased, the degree of polarization increased. Position angle remained unchanged.

1404+28 Although total flux and the degree of polarization remained relatively constant, the position angle changed by 130 degrees in roughly one year.

1442+10 Little activity.

3C309.1 This source shows evidence of low amplitude variations. It possesses a very low degree of polarization.

1502+10 The variations in this source were of a simple form that suggested comparison with the expanding source model. However, the near simultaneity of the peaks at 15.5 and 7.9 GHz, as well as the slightly reduced amplitude at 15.5 GHz in comparison to that at 7.9 GHz suggest that the source was transparent at all times during the outburst at frequencies above 7.9 GHz. The spectral index of the outbursts in the transparent region, calculated by first removing the constant component baseline, was -.25. This implies a value for γ 1.5. Given this value for γ, the degree of polarization should have changed from 14% before the peak in flux density to 65%

afterwards. Unfortunately, the low level of the outburst at 2.7 GHz would have prevented the change in polarization from being noticed.

1510-08 This variable was quite active with several outbursts overlapping. The behavior was smoothed at 2.7 GHz in flux density. Polarization variations in m took place but were not matched in activity by changes in χ. The fact that the outbursts were nearly simultaneous at all frequencies makes it possible that the outbursts in general were transparent. If so, the variations in m may be due to changes in the injected electron energy distribution rather than due to changes in the opacity.

1548+05 Little activity.

1555+00 This source appears to be in the middle of an outburst of several years' duration.

1607+26 An inactive flux density variable, but there are signs of changes in polarization.

1611+34 Little activity, with the exception of possible outbursts in m.

1616+06 Marginal flux density variability.

1624+41 The χ variations are probably a result of noise.

3C345 One broad outburst in flux density of better than 2 years' duration.

1656+05 This source is interesting because of an outburst at 15.5 GHz that is either non-existent at 7.9 GHz and 2.7 GHz or else is so delayed in time that it has not yet been observed. Around the time of the 15.5 GHz peak, there was a change in m.

1722-02 Although constant in flux density and position angle, there were signs of variation in the degree of polarization. This does not fit with the expanding source model.

1730-13 Several minor outbursts are superimposed on one long event.

1741-03 Total flux has been decreasing since 1973.0. Polarization is constant with the possible exception of early 1973.

1749-09 Little activity.

3C371 Little activity.

3C380 The source is decreasing in flux density with small amplitude outbursts superimposed.

3C390.3 Little activity.

3C418 Although polarization has remained constant, there are suggestions of rapid variation in flux density.

2050+36 The polarization variations are most likely caused by noise.

2134+00 The generally monotonic decrease in flux density at 15.5 and 7.9 GHz is not seen at 2.7 GHz; instead, several small outbursts are superimposed on a constant background. The source is almost unpolarized.

2145+06 The monotonic decrease in this source's flux density is apparent at all frequencies.

BL Lac	This very active source has shown several overlapping outbursts, all of which seem to be nearly simulatneous from 31.4 GHz down through 2.7 GHz. There have been large changes in position angle that are of the magnitude predicted by Aller's model. The changes in m were smaller than predicted, but did occur around the times predicted by theory.
2201+31	The shape of variations suggests a slight delay in events between 7.9 and 2.7 GHz.
2216-03	Total flux varied slightly; polarization at 2.7 GHz may have varied more rapidly.
3C446	There may have been a rise in polarized flux in mid-1973 that is uncorrelated with any large flux density event.
CTA102	Little activity.
2243-12	Possible polarized flux outburst, or it may be a systematic error (see Chapter III, part D).
3C454.3	Two nicely-defined outbursts in total flux at frequencies above 2.7 GHz. Little variation in polarization.
2345-16	Large changes in position angle may be due to noise.
3C161	A large change in m occurred around mid-1973 despite constant total flux and degree of polarization.

CHAPTER V

CONCLUSIONS

In general there was good correlation of flux density behavior from 31.4 GHz down through 2.7 GHz. For sources with complete outbursts, the events were often interpretable qualitatively in terms of the expanding source model of van der Laan and its extension by others. The behavior observed in a few objects (3C120 and 3C454.3) strongly suggests that dispersion through an intergalactic medium contributes little to the measured delays in the times of occurrence of a given outburst at several frequencies. Many sources exhibited the behavior expected of objects transparent to synchrotron radiation over a portion of the radio spectrum, typically at frequencies above 7.9 GHz. The 2.7 GHz observations were especially valuable, because many of the outbursts transparent at higher frequencies displayed the time delays and reduced flux density amplitudes at 2.7 GHz that are associated with large opacities in the expanding source model. Nevertheless, numerical analysis of source behavior remains difficult due to the problem of separating the variable components from constant background contributions.

Magnetic fields may be oriented randomly through many of the sources, judging from the low average degrees of polarization and large number of sources showing little polarization variation. However, the large changes in χ for a few of the objects suggests a high degree of order in the magnetic field orientations within some sources. These well-defined changes in position angle support predictions by Aller about how polarization should vary within an expanding source and are another example of how the larger opacities at lower frequencies aid in investigating the expanding source model. A few objects have shown variations in polarization while remaining constant in flux density. One in particular, 3C161, underwent a large outburst in the degree of polarization. This is not readily understood in terms of the expanding source model.

Evidence has been found for several new variable sources, but the search for signs of day to day variations in flux density in a number of objects has turned up negative results.

BIBLIOGRAPHY

Aller, H. D. 1970a, Astrophys. J. 161, 1.

Aller, H. D. 1970b, Astrophys. J. 161, 19.

Aller, H. D. and Haddock, F. T. 1967, Astrophys. J. 147, 833.

Altschuler, D. R. 1974, Ph. D. Thesis, Brandeis University.

Andrew, B. H., Harvey, G. A., and Medd, W. J. 1971, Astrophys. Letters 9, 151.

Andrew, B. H., MacLeod, J. M., Locke, J. L., and Medd, W. J. 1969, Nature 223, 598.

Andrew, B. H., Harvey, G. A., Medd, W. J., Hackney, K. R., Hackney, R. L., Scott, R. L., Smith, A. G., Leacock, R. J., McGimsey, B. Q., Epstein, E. E., Montgomery, J. W., Mottmann, J., and Pomphrey, R. B. 1974, Astrophys. J. 191, 51.

Bignell, R. C. 1973, Astron. J. 78, 557.

Bignell, R. C. and Seaquist, E. R. 1973, Astron. J. 78, 536.

Conway, R. G., Haves, P., Kronberg, P. P., Stannard, D., Vallee, J. P., and Wardle, J. F. C. 1974, Mon. Not. R. Astron. Soc. 168, 137.

Dent, W. A. 1965, Science 148, 1458.

Dent, W. A. and Haddock, F. T. 1966, Astrophys. J. 144, 568.

Dent, W. A. and Hobbs, R. W. 1973, Astron. J. 78, 163.

Dent, W. A., Kapitzky, J. E., and Kojoian, G. 1974, Astron. J. 79, 1232.

Dent, W. A. and Kojoian, G. 1972, Astron. J. 77, 819.

Gardner, F. F., Morris, D., and Whiteoak, J. B. 1969, Aus. J. Phys. 22, 79.

Harvey, G. A., Andrew, B. H., MacLeod, J. M., and Medd, W. J. 1972, Astrophys. Letters 11, 147.

Hobbs, R. W., Hollinger, J. P., and Marandino, G. E. 1968, Astrophys. J. 154, L49.

Hunstead, R. W. 1972, Astrophys. Letters 12, 193.

Kellerman, K. I. 1974, Galactic and Extra-Galactic Radio Astronomy Verschuur, G. L. and Kellerman, K. I., ed. New York:Springer-Verlag, p. 320.

Kellerman, K. I., Jauncey, D. L., Cohen, M. H., Shaffer, B. B., Clark, B. G., Broderick, J., Ronnang, B., Rydbeck, O. E. H., Matveyenko, L., Moiseyev, I., Vitkevitch, V. V., Cooper, B. F. C., and Batchelor, R. 1971, Astrophys. J. 169, 1.

Kellerman, K. I. and Pauliny-Toth, I. I. K. 1967, Nature 213, 977.

Kellerman, K. I., Pauliny-Toth, I. I. K., and Tyler, W. C. 1968, Astron. J. 73, 298.

Kellerman, K. I., Pauliny-Toth, I. I. K., and Williams, P. J. S. 1969, Astrophys. J. 157, 1.

Laan, H. van der 1966, Nature 211, 1131.

MacLeod, J. M., Andrew, B. H., Medd, W. J., and Olsen, E. T. 1971, Astrophys. Letters 9, 19.

Maltby, P. and Seielstad, G. A. 1966, Astrophys. J. 144, 216.

Manchester, R. N. 1974, Galactic and Extra-Galactic Radio Astronomy Verschuur, G. L. and Kellerman, K. I., ed. New York:Springer-Verlag, p. 140.

Medd, W. J., Andrew, B. H., Harvey, G. A., and Locke, J. L. 1972, Mem. R. Astron. Soc. 77, 109.

Morris, D. and Berge, G. L. 1964, Astron. J. 69, 641.

Pacholczyk, A. G. and Swihart, T. L. 1967, Astrophys. J. 150, 647.

Pacholczyk, A. G. and Swihart, T. L. 1970, Astrophys. J. 161, 415.

Pacholczyk, A. G. and Swihart, T. L. 1971, Astrophys. J. 170, 405.

Pacholczyk, A. G. and Swihart, T. L. 1973, Astrophys. J. 179, 21.

Pacholczyk, A. G. and Swihart, T. L. 1974, Astrophys. J. 192, 591.

Pauliny-Toth, I. I. K. and Kellerman, K. I. 1966, Astrophys. J. 146, 634.

Peterson, F. W. and Dent, W. A. 1973, Astrophys. J. 186, 421.

Seielstad, G. A. and Berge, G. L. 1975, Astron. J. 80, 271.

Stull, M. A. 1972, Astron. J. 77, 13.

Takarada, K. 1970, Pub. Astron. Soc. Jap. 22, 551.

Wardle, J. F. C. and Kronberg, P. P. 1974, Astrophys. J. 194, 249.

Wills, B. J. 1971, Astrophys. J. 169, 221.

APPENDIX I

TABULAR PRESENTATION OF DATA FOR VARIABLE SOURCES

This appendix presents the 2.7 GHz numerical data for each variable source. The sources with their names and indices of variability (η's) are listed in order of right ascension. The first column gives the date of observation, the next two give the flux density and error in Janskys, the next two give the degree of polarization and error in percent, and the next two columns give the position angle and error in degrees. The last two columns give the number of points used in determining the flux density (NS) and polarization properties (NP). Averages for all quantities over all runs follow the individual measurements.

0048-09

VARIABILITY INDEX= 4.8

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.39	.02					4	
1973.04	2.14	.04	.6	.9	13.2	24.3	3	3
1973.26	1.84	.11	1.5	.9	88.8	5.2	4	3
1973.40	1.54	.05	2.5	1.1	82.4	4.7	4	4
1973.64	1.59	.02	1.0	.9	109.6	21.6	5	4
1973.88	1.51	.04	4.0	1.0	92.6	2.1	5	5
1974.16	1.68	.02	3.7	.8	90.9	2.6	5	4
1974.49	1.89	.09	1.9	1.5	87.0	6.9	4	4
1974.90	1.95	.03	3.5	.5	83.2	1.6	5	5
1975.17	1.81	.07	2.4	1.2	103.9	9.0	1	1
1975.45	1.69	.05	3.3	.9	77.5	4.9	2	2
1975.63	1.42	.03	4.4	.7	90.0	1.6	7	7
AVERAGES	1.70	.07	2.4	.4	88.7	5.2	12	11

0105+01

VARIABILITY INDEX= 8.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.51	.02					4	
1973.04	2.84	.07	1.6	.4	106.5	4.7	4	4
1973.26	2.92	.20					4	
1973.40	3.00	.04	1.8	.3	107.2	4.0	4	4
1973.63	3.06	.02	2.1	.3	99.6	2.3	4	4
1973.88	3.29	.02	1.2	.2	107.3	3.6	4	4
1974.17	3.69	.04	1.1	.4	88.6	4.4	3	3
1974.49	3.98	.05	1.0	.2	140.0	15.5	2	2
1974.90	3.84	.02	1.4	.2	112.6	3.7	6	6
1975.17	3.57	.07	1.5	.4	127.4	15.1	1	1
1975.45	3.48	.05	1.0	.3	125.0	15.1	2	2
1975.63	3.32	.01	1.0	.1	122.8	5.4	6	6
AVERAGES	3.29	.13	1.2	.2	111.7	3.9	12	10

0119+11 VARIABILITY INDEX= 3.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	.82	.02					3	
1973.04	.81	.03					2	
1973.26	.92	.04					1	
1973.41	.67	.04					1	
1973.63	.79	.03					2	
1973.87	.74	.02					3	
1974.16	.87	.02					3	
1974.50	.85	.04					1	
1974.90	.88	.03					2	
1975.45	.97	.04					1	
1975.63	.92	.02					3	
AVERAGES	.84	.03					11	

0133+47 (DA55) VARIABILITY INDEX= 19.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.64	.02					3	
1973.04	1.62	.03	4.9	1.1	1.9	2.2	2	2
1973.26	1.40	.03	5.9	1.1	5.7	2.3	2	2
1973.40	1.42	.03	2.4	1.3	9.3	7.1	2	2
1973.64	1.49	.02	3.9	.9	9.4	3.3	3	3
1973.87	1.61	.02	1.5	.7	28.2	16.7	3	2
1974.16	2.08	.03	5.0	.7	4.0	1.5	3	3
1974.50	2.63	.05	4.3	1.0	.5	2.5	1	1
1974.90	2.99	.03	2.7	.5	7.1	2.4	3	3
1975.45	2.78	.05	.5	.8	70.1	36.8	1	1
1975.63	2.66	.04	2.7	2.5	91.1	3.9	2	1
AVERAGES	2.[illegible]3	.19	2.6	.8	6.9	8.8	11	10

NGC1052

VARIABILITY INDEX= 5.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	.49	.04					1	
1973.14	.58	.03					2	
1973.27	.58	.03					2	
1973.41	.59	.03					2	
1973.63	.65	.04					1	
1973.88	.67	.03					2	
1974.16	.68	.02					3	
1974.49	.84	.04					1	
1974.90	.91	.03					3	
1975.17	.83	.04					1	
1975.45	.94	.04					1	
1975.63	.94	.02					5	
AVERAGES	.72	.05					12	

CTA21

VARIABILITY INDEX= 1.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	5.08	.08					1	
1973.14	5.07	.06	.8	.5	1.9	6.9	2	2
1973.26	5.13	.06	.9	.5	176.3	5.7	2	2
1973.41	5.16	.06	.5	.4	10.1	13.5	2	2
1973.64	5.18	.06	.8	.4	12.4	9.5	2	2
1973.88	5.05	.06	.2	.5	178.0	34.6	2	2
1974.16	5.22	.05	.6	.4	179.0	6.7	3	3
1974.49	5.07	.08	.8	.7	5.6	12.4	1	1
1974.90	5.11	.05	.5	.4	93.3	8.2	3	3
1975.17	5.10	.08	.2	.3	145.8	71.8	1	1
1975.45	5.17	.08	.4	.7	179.3	17.2	1	1
1975.63	5.22	.02	.8	.3	171.5	5.3	4	4
AVERAGES	5.13	.02	.4	.1	[illegible]	7.9	12	11

3C84 VARIABILITY INDEX= 11.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	17.32	.14					3	
1973.04	17.90	.18	.0	.4	178.0	99.0	2	2
1973.26	18.88	.19	.5	.3	11.6	11.8	2	2
1973.40	19.46	.19	.5	.4	4.1	8.1	2	2
1973.64	19.53	.16	.4	.3	9.6	12.0	3	3
1973.88	20.02	.16	.1	.2	118.2	53.7	3	3
1974.16	21.08	.17	.1	.3	8.6	71.2	3	3
1974.49	22.12	.31					1	
1974.90	22.97	.19	.8	.3	89.0	4.5	3	3
1975.16	23.79	.33	.4	.4	74.5	22.3	1	1
1975.45	24.37	.34	.1	.5	1.6	46.9	1	1
1975.63	24.75	.20	.1	.1	143.5	68.4	3	3
AVERAGES	21.0	.7	0.0	.1	23.3	43.7	12	10

0333+32 (NRAO140) VARIABILITY INDEX= 3.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.38	.06					1	
1973.04	3.09	.04	2.2	.6	89.9	3.0	2	2
1973.26	2.97	.03	1.4	.5	90.6	3.8	3	3
1973.41	3.14	.04	2.2	.6	95.5	3.3	2	2
1973.64	3.32	.04	2.2	.6	90.3	2.9	2	2
1973.88	2.98	.03	2.8	.5	94.3	2.1	3	3
1974.16	3.14	.03	3.1	.5	94.0	1.8	3	3
1974.49	3.07	.06	1.9	.9	93.5	5.1	1	1
1974.90	3.05	.04	3.6	.6	95.1	2.0	2	2
1975.17	3.02	.05	2.6	.9	94.5	3.9	1	1
1975.45	3.03	.05	3.8	2.0	97.9	4.9	1	1
1975.64	3.31	.02	2.4	.2	98.4	1.6	6	6
AVERAGES	3.13	.04	2.6	.2	94.4	2.3	12	11

CTA26

VARIABILITY INDEX= 10.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.97	.04					3	
1973.04	2.58	.04	3.2	.6	168.6	2.8	2	3
1973.26	2.98	.05	1.2	.5	150.6	18.4	2	1
1973.40	2.78	.05	3.3	.7	171.8	2.7	2	2
1973.64	2.52	.04	2.1	.5	166.9	4.3	3	3
1973.88	2.26	.03	2.9	.8	173.5	3.3	3	2
1974.16	2.01	.03	2.5	.5	167.1	3.4	4	4
1974.50	1.91	.05	2.8	1.2	172.3	5.8	1	1
1974.90	2.02	.03	1.1	.6	165.3	10.5	3	3
1975.16	2.24	.06	1.2	.9	18.8	17.2	1	1
1975.45	1.86	.05	4.7	1.4	176.1	3.6	1	1
1975.63	1.86	.03	3.5	.9	177.0	2.9	3	2
AVERAGES	2.33	.12	2.5	.4	172.1	4.1	12	11

NRAO150

VARIABILITY INDEX= 2.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	6.07	.06					2	
1973.04	5.58	.06	2.5	.3	104.3	2.5	2	3
1973.27	5.94	.09	2.7	.6	97.6	3.0	1	1
1973.40	5.60	.06	2.4	.4	105.5	3.6	2	2
1973.63	5.54	.06	2.8	.4	104.1	2.7	2	2
1973.88	5.62	.05	2.4	.3	105.3	2.7	3	3
1974.16	5.57	.10	3.7	.3	99.2	1.5	4	4
1974.50	5.61	.09	1.6	.5	111.[illegible]	8.1	1	1
1974.90	5.68	.28	2.4	.3	102.8	2.4	3	3
1975.16	5.55	.09	2.1	.6	99.8	4.2	1	1
1975.45	5.44	.08	2.0	.5	108.9	6.3	1	1
1975.63	5.74	.05	3.0	.3	100.7	1.8	3	3
AVERAGES	5.66	.05	2.5	.2	103.[illegible]	1.9	12	11

0405-12 VARIABILITY INDEX= 1.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.28	.09					1	
1973.04	2.34	.07	1.0	.6	124.3	40.3	2	2
1973.26	2.25	.05	1.0	.3	131.8	27.7	3	3
1973.41	2.39	.07	2.4	1.6	103.4	10.3	2	1
1973.63	2.32	.07	5.2	2.3	175.9	2.8	2	1
1973.88	2.25	.07	.7	.9	105.6	22.9	2	2
1974.16	2.40	.07	.9	.6	106.4	15.2	2	2
1974.49	2.57	.10	1.3	.7	115.7	17.6	1	1
1974.90	2.48	.07	1.4	.7	107.9	10.8	2	2
1975.17	2.26	.09	1.5	1.1	98.6	9.6	1	1
1975.45	2.52	.10	1.7	3.2	98.4	18.5	1	1
1975.63	2.39	.07	1.2	.7	96.6	7.7	2	2
AVERAGES	2.37	.03	.8	.3	118.5	11.4	12	11

0420-01 VARIABILITY INDEX= 2.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.18	.01					4	
1973.04	1.21	.02	1.8	1.1	83.1	6.4	4	4
1973.26	1.19	.02	3.1	1.1	86.2	4.0	3	3
1973.40	1.16	.02	2.7	1.2	84.4	4.4	4	4
1973.63	1.16	.01	3.0	1.2	83.4	3.9	4	4
1973.88	1.19	.02	2.8	.8	87.5	2.7	5	4
1974.16	1.21	.02	1.7	.5	86.5	4.0	7	7
1974.49	1.11	.03	3.6	1.4	79.4	5.6	2	2
1974.90	1.14	[illegible]	2.0	.6	84.7	4.5	4	4
1975.16	1.22	.03	2.2	1.2	75.9	10.0	2	2
1975.45	1.09	.03	1.1	1.3	73.5	28.2	2	2
1975.64	1.16	.02	1.7	1.0	76.2	10.7	5	3
AVERAGES	1.17	.01	2.3	.2	82.5	2.8	12	11

3C120

VARIABILITY INDEX= 7.2

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	7.25	.07					3	
1973.04	8.09	.09	2.8	.3	170.5	1.7	2	3
1973.27	8.87	.10	1.9	.5	173.1	3.8	2	1
1973.40	9.28	.10	2.5	.4	[illegible]	1.8	2	2
1973.63	9.60	.11	2.3	.4	176.5	2.0	2	2
1973.87	9.11	.08	2.4	.4	174.8	2.0	3	2
1974.16	8.15	.12	2.2	.3	170.4	2.3	4	4
1974.50	8.00	.13	3.0	.6	173.4	2.4	1	1
1974.90	8.17	.08	1.9	.3	168.0	2.7	3	3
1975.16	9.42	.15	1.5	.5	172.7	4.8	1	1
1975.45	9.65	.15	1.8	.5	173.5	4.1	1	1
1975.63	9.18	.10	1.6	.4	171.6	3.3	2	2
AVERAGES	8.73	.22	2.2	.1	173.3	1.9	12	11

0440-00 (NRAO190) VARIABILITY INDEX= 6.2

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.73	.04					3	
1973.04	2.77	.04	2.3	.5	13.[illegible]	3.8	2	3
1973.26	3.01	.05	1.3	.2	47.8	13.5	2	2
1973.40	2.74	.04	1.8	.3	43.7	11.3	2	2
1973.63	2.67	.04	1.3	.3	42.5	15.4	2	2
1973.88	2.72	.04	1.6	.2	50.9	9.6	3	3
1974.16	2.60	.03	2.2	.3	59.1	6.6	3	3
1974.50	2.60	.06	2.3	.6	60.1	10.9	1	1
1974.90	2.46	.03	1.8	.4	66.0	7.5	3	3
1975.16	2.26	.05	2.4	.6	56.4	12.1	1	1
1975.45	2.25	.05	1.8	.4	42.3	17.1	1	1
1975.63	2.36	.04	1.6	.4	35.2	14.3	2	2
AVERAGES	2.57	.08	1.6	.1	47.8	2.0	12	11

0458-02 VARIABILITY INDEX= 4.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.53	.05					1	
1973.03	1.87	.04	4.4	1.5	176.0	3.4	2	1
1973.26	1.81	.04	.9	1.3	175.8	17.1	2	1
1973.41	2.11	.04	1.3	.8	162.7	12.6	2	2
1973.63	1.95	.04	.7	.7	123.9	52.7	2	1
1973.88	1.85	.03	2.9	.7	174.7	3.0	3	3
1974.16	2.11	.03	.2	.4	141.8	90.0	3	2
1974.49	1.90	.04	.2	1.0	72.7	90.0	2	2
1974.90	1.91	.04	.9	.5	122.8	26.5	2	2
1975.45	1.84	.05					1	
1975.63	1.66	.03	1.4	.7	119.0	20.0	3	2
AVERAGES	1.87	.05	.9	.5	164.3	13.9	11	9

0552+39 (OA198) VARIABILITY INDEX= 3.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.98	.04					3	
1973.04	3.79	.04	.1	.2	112.9	90.0	5	5
1973.26	3.93	.05	.4	.4	92.3	11.0	6	3
1973.40	3.83	.04	1.1	.4	1.2	5.8	3	3
1973.64	3.65	.04	.5	.3	25.5	22.4	3	3
1973.88	3.83	.03	.7	.2	91.0	4.5	6	5
1974.16	3.85	.03	.1	.1	139.2	71.8	7	7
1974.49	3.77	.04	.3	.3	136.6	76.9	3	1
1974.90	3.67	.02	1.4	.2	96.1	2.7	5	5
1975.16	3.96	.05	.5	.6	67.9	35.4	2	1
1975.45	3.87	.05	.4	.5	84.0	16.2	2	2
1975.63	3.96	.02	.4	.5	87.7	7.0	6	6
AVERAGES	3.84	.03	.1	.2	89.2	25.9	12	11

0605-08

VARIABILITY INDEX= 4.2

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.87	.07					2	
1973.03	3.06	.07	.6	.8	162.7	29.1	2	2
1973.26	3.34	.06	1.2	.5	173.1	4.9	3	3
1973.40	3.71	.12	.7	.7	167.9	18.1	1	1
1973.63	3.71	.08	1.1	1.1	172.5	10.8	2	1
1973.88	3.72	.07	1.9	.4	80.7	3.3	3	3
1974.16	3.82	.04	1.0	.2	56.5	9.9	4	4
1974.50	3.77	.12	2.0	.3	41.3	10.8	1	1
1974.90	3.65	.07	1.0	.3	58.3	14.7	3	2
1975.16	3.13	.10	.8	.4	52.9	31.1	1	1
1975.45	3.14	.10	1.0	.4	51.8	23.7	1	1
1975.63	3.21	.07	.7	.2	46.9	23.5	2	2
AVERAGES	3.43	.10	.5	.2	42.7	12.3	12	11

0607-15

VARIABILITY INDEX= 4.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.32	.07					1	
1973.04	1.71	.06	.9	2.3	8.7	24.4	2	2
1973.26	2.02	.06	.6	.5	56.6	42.8	3	3
1973.40	1.91	.07	3.9	2.0	2.6	3.9	2	1
1973.64	2.12	.08	3.2	1.0	31.8	16.2	2	2
1973.88	2.15	.06	1.9	1.7	87.8	5.0	2	2
1974.16	2.24	.07	2.2	.9	83.2	4.1	3	3
1974.49	1.87	.07	1.2	.9	5.5	9.1	2	2
1974.90	1.66	.06	3.5	1.2	83.9	3.7	2	2
1975.17	1.65	.09	1.8	.6	44.6	28.8	1	1
1975.45	1.76	.09	3.5	3.4	84.6	8.3	1	1
1975.63	1.45	.04	1.5	1.1	71.1	17.7	4	2
AVERAGES	1.82	.08	.9	.4	59.2	11.8	12	11

0723-00

VARIABILITY INDEX= 7.8

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.92	.03					3	
1973.04	1.84	.02	3.8	.3	121.3	4.5	5	5
1973.26	1.86	.02	3.9	.3	122.0	3.0	5	5
1973.40	1.86	.04	3.6	.6	118.2	6.9	2	2
1973.63	1.81	.04	3.5	.4	117.7	4.0	4	4
1973.88	1.91	.04	3.0	.2	118.6	3.1	6	6
1974.16	2.02	.02	3.8	.2	118.8	2.6	6	6
1974.50	2.23	.03	2.3	.4	115.9	6.7	3	3
1974.90	2.32	.02	2.4	.2	121.3	4.1	5	5
1975.16	2.39	.04	2.5	.7	115.9	9.8	2	1
1975.45	2.37	.04	1.9	.4	124.4	10.4	2	2
1975.63	2.34	.03	1.4	.5	150.6	13.9	5	2
AVERAGES	2.07	.07	2.8	.2	120.5	2.4	12	11

0727-11

VARIABILITY INDEX= 6.8

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.40	.05					3	
1973.04	2.75	.04	2.4	1.0	171.0	4.2	4	5
1973.26	2.73	.04	.7	.4	164.5	10.5	5	5
1973.40	2.77	.08	4.9	1.4	.8	2.1	2	1
1973.63	3.03	.03	4.8	.8	175.5	1.4	4	3
1973.88	2.71	.06	.7	.3	136.4	50.0	3	2
1974.16	2.95	.04	2.4	.4	94.5	1.5	7	7
1974.49	3.50	.08	.9	.4	111.0	10.7	3	3
1974.90	3.67	.04	2.0	.4	101.8	3.9	5	5
1975.17	3.55	.14					1	
1975.45	3.46	.09	2.4	1.0	89.3	3.5	2	2
1975.63	3.29	.05	2.1	.5	87.5	2.2	5	5
AVERAGES	3.07	.12	0.0	.6	154.7	31.7	12	10

0735+17

VARIABILITY INDEX= 8.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.88	.03					2	
1973.04	1.86	.03	3.2	.3	48.0	6.7	3	3
1973.26	1.84	.03	2.6	.3	45.6	8.2	3	3
1973.40	1.89	.04	2.5	.7	59.0	13.0	1	1
1973.63	2.04	.03	2.9	.5	31.6	7.5	2	2
1973.88	1.94	.03	2.0	.4	59.4	9.1	3	3
1974.16	2.08	.02	1.3	.7	80.5	7.5	4	4
1974.50	1.99	.04	1.7	1.0	70.3	14.7	1	1
1974.90	2.18	.03	1.1	.4	60.1	15.5	3	3
1975.45	2.61	.05	6.1	1.5	81.2	3.0	1	1
1975.63	2.50	.04	1.2	.3	49.4	19.1	2	2
AVERAGES	2.07	.08	2.3	.4	60.0	5.3	11	10

0735+01

VARIABILITY INDEX= 3.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.95	.05					1	
1973.04	2.11	.04	6.3	.9	82.5	1.7	2	2
1973.26	2.03	.03	5.8	.7	82.7	1.5	3	3
1973.40	1.85	.05	4.7	1.4	85.5	3.1	1	1
1973.64	1.87	.03	5.4	.9	79.9	2.3	2	2
1973.88	1.85	.03	5.3	.7	81.3	1.9	3	3
1974.16	1.78	.03	5.6	.8	83.3	1.7	3	3
1974.49	1.81	.03	5.4	.9	84.9	2.0	2	2
1974.90	1.79	.03	5.1	.8	87.6	1.6	3	3
1975.17	1.82	.05					1	
1975.45	2.02	.05	4.2	1.2	82.6	4.6	1	1
1975.63	1.90	.03	3.9	.7	84.9	2.2	3	3
AVERAGES	1.90	.03	5.2	.2	83.4	1.2	12	10

0831+55

VARIABILITY INDEX= .9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	7.48	.08					2	
1973.04	7.66	.02	.3	.2	92.5	5.1	5	5
1973.26	7.52	.02	.2	.1	73.5	13.7	5	5
1973.40	7.60	.08	.2	.4	103.5	43.1	2	2
1973.63	7.56	.04	.2	.2	78.1	16.5	4	4
1973.88	7.49	.07	.2	.1	93.2	9.8	6	6
1974.16	7.58	.07	.5	.2	93.6	4.3	7	7
1974.49	7.55	.06	.1	.3	5.0	35.7	3	3
1974.90	7.38	.37	.1	.2	41.3	75.7	6	5
1975.16	7.53	.08	.3	.4	88.3	14.1	2	2
1975.45	7.58	.08	.4	.6	172.8	18.6	2	1
1975.63	7.60	.05	.3	.3	4.3	10.0	5	5
AVERAGES	7.54	.02	.0	.1	86.7	24.4	12	11

OJ287

VARIABILITY INDEX= 13.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.17	.03					2	
1973.04	3.13	.01	2.5	.4	166.1	3.3	4	3
1973.26	3.48	.02	.9	.2	141.0	5.5	6	6
1973.40	3.58	.08	3.[illegible]	.3	3.5	1.1	4	4
1973.63	3.16	.01	1.8	.4	10.9	2.9	4	4
1973.88	3.60	.03	.9	.1	66.3	4.5	6	6
1974.16	3.53	.03	3.9	.2	92.5	.7	6	6
1974.49	2.84	.03	6.7	.5	96.8	1.0	3	3
1974.90	2.99	.02	10.8	.4	101.4	.7	6	6
1975.16	3.03	.04	6.2	.6	102.3	1.6	2	2
1975.63	2.89	.04	5.2	.4	97.7	1.0	5	5
AVERAGES	3.15	.14	2.4	1.3	101.5	13.7	11	10

0859-14

VARIABILITY INDEX= 2.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.66	.09					2	
1973.14	3.05	.08	5.0	.8	92.2	.9	3	5
1973.26	2.92	.07	4.5	.6	93.1	2.2	4	4
1973.40	2.93	.08	3.6	.8	92.6	1.6	3	3
1973.63	3.03	.04	5.1	.8	91.1	.9	4	4
1973.88	2.98	.05	4.0	.6	93.8	1.3	6	6
1974.16	3.04	.03	3.5	.4	94.3	1.2	7	7
1974.49	3.13	.08	4.2	.6	93.6	1.3	3	3
1974.90	3.05	.08	4.8	.6	92.3	1.2	3	3
1975.17	2.95	.09	3.8	.9	94.8	2.8	2	2
1975.45	3.27	.15					1	
1975.63	3.17	.07	4.4	.6	92.0	1.2	5	5
AVERAGES	3.02	.04	4.3	.2	92.9	1.2	12	10

4039.25

VARIABILITY INDEX= 1.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	5.01	.08					1	
1973.14	5.16	.06	.7	.5	176.0	7.4	2	2
1973.26	4.96	.04	2.1	.4	.8	2.0	3	3
1973.40	5.08	.06	2.6	.5	.8	2.0	2	2
1973.64	5.06	.06	1.1	.6	14.5	10.7	2	1
1973.88	5.02	.05	.4	.4	2.1	10.7	3	3
1974.16	5.09	.05	.8	.4	.3	5.2	3	3
1974.49	4.92	.05	2.5	.5	176.4	2.1	2	2
1974.90	4.83	.04	1.4	.4	3.5	3.2	3	3
1975.17	5.03	.08	.5	.4	57.8	37.5	1	1
1975.45	5.08	.08					1	
1975.63	5.12	.05	3.1	.5	.4	1.7	3	2
AVERAGES	5.03	.03	1.4	.3	1.6	6.9	12	10

M82 VARIABILITY INDEX= 2.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	5.29	.09					1	
1973.04	5.05	.05	.9	.3	18.8	8.2	3	3
1973.26	5.16	.05	.7	.3	20.8	11.4	3	3
1973.40	5.02	.06	1.0	.4	16.9	8.6	2	2
1973.63	5.12	.06	1.2	.4	14.1	6.4	2	2
1973.88	5.01	.05	.7	.3	22.0	12.2	3	3
1974.16	5.01	.07	.7	.2	16.1	5.9	4	4
1974.49	4.97	.05	1.1	.3	13.8	6.[illegible]	3	3
1974.90	4.56	.23	.3	.3	16.6	27.2	3	3
1975.16	4.98	.08	.7	.6	18.5	19.7	1	1
1975.45	5.20	.09	.7	.6	11.6	14.2	1	1
1975.63	5.01	.06	.9	.4	11.8	7.6	2	2
AVERAGES	5.03	.05	.8	.1	16.1	2.3	12	11

[illegible]953+25 (OK290) VARIABILITY INDEX= 2.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.12	.04					1	
1973.04	1.20	.03	.9	1.3	80.4	21.5	2	2
1973.26	1.21	.02	.1	1.1	97.5	90.0	3	3
1973.40	1.14	.03	2.0	1.4	81.9	9.[illegible]	2	2
1973.64	1.14	.03	1.6	1.3	23.9	19.8	2	2
1973.88	1.15	.02	1.1	.5	49.0	37.1	3	2
1974.16	1.14	.03	.8	1.9	80.9	31.8	2	1
1974.49	1.19	.03	.4	.8	49.7	90.0	2	1
1974.90	1.16	.02	.8	1.4	3.6	18.6	3	2
1975.17	1.21	.04	3.7	1.9	3.3	5.6	1	1
1975.45	1.32	.03	4.3	1.2	7.9	4.4	2	2
1975.63	1.30	.02	5.7	1.1	4.8	2.4	3	3
AVERAGES	1.19	.02	1.[illegible]	.6	14.4	15.3	12	11

1055+01

VARIABILITY INDEX= 2.8

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.77	.04					2	
1973.04	2.96	.01	3.6	.4	84.4	1.0	6	6
1973.26	2.92	.04	3.7	.4	88.6	1.0	6	5
1973.40	2.87	.04	4.4	.7	90.1	1.2	4	4
1973.63	2.80	.02	3.8	.4	89.7	1.1	4	4
1973.88	2.79	.03	3.9	.3	91.9	1.0	6	6
1974.16	2.77	.04	4.1	.3	90.0	.8	6	6
1974.49	2.67	.04	4.1	.3	91.5	1.1	5	5
1974.90	2.80	.03	3.9	.4	91.2	1.3	5	5
1975.17	2.79	.04	4.3	.7	94.2	1.7	2	2
1975.45	2.89	.03	3.9	.6	96.2	1.9	3	3
1975.63	3.01	.03	4.4	.4	98.8	1.3	5	5
AVERAGES	2.84	.03	4.0	.1	91.7	.6	12	11

1127-14

VARIABILITY INDEX= 1.5

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	6.70	.22					2	
1973.04	6.46	.08	1.9	.6	4.8	2.2	4	4
1973.26	6.50	.16	1.6	.3	15.5	3.0	6	5
1973.40	6.59	.13	1.7	.3	11.8	2.8	5	4
1973.63	6.66	.14	4.1	.6	3.0	1.0	4	4
1973.87	6.52	.21	2.7	.7	6.8	3.1	2	1
1974.16	6.31	.09	.8	.3	19.8	9.1	7	7
1974.49	6.25	.09	1.3	.5	13.3	5.9	4	4
1974.90	6.27	.06	2.1	.8	59.5	8.0	4	4
1975.17	6.15	.20	2.6	.2	43.7	4.8	2	2
1975.45	6.16	.16	1.2	.3	22.2	8.1	3	2
1975.63	6.24	.06	1.2	.3	19.3	6.2	4	4
AVERAGES	6.40	.06	1.5	.3	17.6	6.3	12	11

1215+30 VARIABILITY INDEX= 1.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	.53	.03					2	
1973.04	.51	.02					3	
1973.26	.53	.01					4	
1973.40	.52	.01					5	
1973.63	.54	.01					4	
1973.88	.55	.02					3	
1974.16	.53	.03					7	
1974.49	.54	.01					4	
1974.98	.49	.01					5	
1975.17	.54	.04					1	
1975.45	.51	.03					2	
1975.63	.50	.02					4	
AVERAGES	.52	.01					12	

3C273 VARIABILITY INDEX= 1.5

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	40.7	.7					1	
1973.04	41.2	.4	2.6	.2	161.2	2.2	3	3
1973.26	41.4	.4	3.0	.3	162.6	2.2	3	2
1973.41	41.2	.5	2.3	.4	162.8	4.1	2	1
1973.63	41.6	.5	2.6	.3	166.8	2.2	2	2
1973.88	41.8	.4	2.3	.3	160.7	3.1	3	2
1974.16	42.0	.2	2.1	.2	155.5	3.2	4	3
1974.49	42.4	.4	2.2	.3	161.2	3.2	3	2
1974.98	43.4	.4	1.5	.2	151.6	4.9	3	3
1975.16	42.5	.7	1.4	.3	146.2	9.4	1	1
1975.45	41.2	.7	1.3	.3	150.0	9.7	1	1
1975.63	42.2	.5	1.8	.3	157.0	4.4	2	2
AVERAGES	41.8	.2	2.1	.2	159.3	2.1	12	11

3C274 VARIABILITY INDEX= 1.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	111.1	1.6					1	
1973.04	115.9	1.2	.2	.3	6.7	29.3	2	2
1973.26	119.6	1.0	.3	.3	3.3	10.9	3	3
1973.40	114.9	.9	.3	.3	2.6	11.9	3	3
1973.64	117.5	1.2	.9	.3	12.2	6.1	2	2
1974.16	118.5	1.0	.1	.3	1.9	36.1	3	3
1974.49	115.8	1.2	.5	.3	9.7	11.4	2	2
1974.90	118.5	1.2	.2	.2	62.2	38.4	2	2
1975.17	115.8	1.6	.3	.5	78.8	22.9	1	1
1975.45	117.1	1.7	.5	.5	77.4	17.4	1	1
1975.63	118.1	1.0	.4	.3	2.3	7.6	3	3
AVERAGES	116.6	.7	.2	.1	17.2	13.8	11	10

3C279 VARIABILITY INDEX= 5.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	12.71	.32					1	
1973.04	13.18	.12	3.0	.1	147.1	1.7	5	5
1973.26	12.83	.17	3.3	.1	149.2	2.0	5	5
1973.40	12.82	.18	2.7	.2	146.2	3.1	5	3
1973.63	13.35	.08	2.6	.1	148.0	1.8	4	4
1973.88	12.77	.18	2.7	.3	156.3	3.1	3	2
1974.17	12.32	.14	2.3	.1	137.3	1.6	6	6
1974.49	11.65	.16	1.8	.1	137.7	2.0	5	5
1974.90	11.71	.07	1.7	.1	117.3	2.9	5	5
1975.17	11.47	.20	1.8	.2	119.1	5.3	2	2
1975.45	10.84	.16	1.2	.2	118.3	6.6	3	3
1975.63	11.23	.17	1.4	.1	114.4	3.1	6	6
AVERAGES	12.24	.24	2.0	.2	139.8	2.9	12	11

1345+12 VARIABILITY INDEX= .6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.86	.05					2	
1973.04	3.83	.03	.2	.2	148.7	29.3	5	5
1973.27	3.87	.04	.5	.2	167.8	7.6	5	5
1973.40	3.82	.04	.4	.2	174.0	7.6	5	5
1973.63	3.80	.06	.6	.2	1.2	5.3	4	4
1973.88	3.80	.04	.4	.4	174.4	11.9	3	3
1974.16	3.82	.05	.2	.1	147.5	18.8	7	7
1974.49	3.82	.03	.5	.2	171.5	6.6	5	5
1974.90	3.86	.07	.3	.2	63.9	16.9	5	4
1975.17	3.85	.05	.2	.4	159.2	47.1	2	2
1975.45	3.86	.04	1.2	.5	90.9	4.2	3	3
1975.63	3.87	.03	.3	.2	157.5	16.8	5	5
AVERAGES	3.84	.01	.1	.1	163.0	20.0	12	11

1354-15 (OP-192) VARIABILITY INDEX= 4.2

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.86	.07					2	
1973.04	1.67	.01	1.5	1.1	150.5	33.6	4	3
1973.26	1.65	.03	4.4	1.5	95.3	3.0	5	2
1973.40	1.72	.02	3.8	1.2	98.8	3.9	4	4
1973.63	1.67	.05	3.5	1.8	98.6	5.2	3	3
1973.88	1.49	.06	3.1	2.1	101.6	9.1	2	2
1974.16	1.68	.04	3.9	.8	97.6	2.2	6	6
1974.49	1.58	.05	3.9	.7	99.2	2.6	4	4
1974.90	1.44	.04	5.5	.9	95.7	1.8	5	5
1975.17	1.41	.05	5.6	1.5	81.7	3.6	2	2
1975.45	1.28	.04	3.9	1.6	104.7	8.7	3	1
1975.63	1.30	.05	4.3	1.4	99.7	4.2	5	4
AVERAGES	1.56	.05	3.6	.5	97.6	3.8	12	11

1404+28 (OQ208) VARIABILITY INDEX= 1.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.93	.04					1	
1973.04	2.04	.03	.1	.3	130.0	90.0	3	3
1973.27	2.03	.03	.5	.6	67.0	33.9	2	2
1973.40	2.01	.03	1.0	.8	81.0	11.7	2	2
1973.64	2.03	.03	.4	.7	60.6	82.1	2	1
1973.88	2.03	.03	.3	.7	5.2	23.1	3	3
1974.16	2.03	.03	.9	.7	176.1	8.2	3	3
1974.49	2.05	.03	.8	.6	9.8	12.5	3	3
1974.90	1.92	.03	.3	.4	36.1	81.9	2	2
1975.16	1.98	.04	.6	.8	28.0	47.5	1	1
1975.45	2.04	.05					1	
1975.63	2.07	.03	2.4	.8	3.9	3.8	3	2
AVERAGES	2.01	.01	.3	.2	16.9	17.3	12	10

1442+10 (OQ172) VARIABILITY INDEX= 3.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.88	.03					3	
1973.04	1.86	.01	.9	.4	70.9	9.8	5	5
1973.26	1.72	.01	.7	.2	47.9	17.4	6	6
1973.40	1.78	.01	1.1	.4	73.0	8.1	5	5
1973.63	1.82	.02	.7	.2	30.8	11.0	5	5
1973.88	1.90	.03	.3	.4	54.4	73.7	2	2
1974.16	1.82	.02	.6	.2	57.9	14.2	7	7
1974.49	1.75	.03	.6	.2	48.8	15.3	4	4
1974.90	1.67	.03	1.1	.3	38.0	15.1	6	6
1975.16	1.74	.04	1.2	1.0	68.3	24.6	1	1
1975.45	1.71	.02	1.5	.5	59.9	13.2	3	3
1975.63	1.77	.03	1.7	.5	69.7	8.0	5	5
AVERAGES	1.79	.02	.8	.1	58.9	3.7	12	11

3C309.1 VARIABILITY INDEX= 2.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	5.54	.07					2	
1973.04	5.39	.05	.5	.4	82.8	10.8	3	3
1973.26	5.26	.05	.6	.4	87.9	7.4	3	3
1973.40	5.41	.06	.2	.6	174.2	25.3	2	2
1973.63	5.33	.06	.3	.5	3.7	21.4	2	2
1973.88	5.37	.05	1.3	.4	87.4	3.3	3	3
1974.16	5.26	.25	.1	.3	31.8	90.0	4	4
1974.49	5.20	.05	.2	.4	6.4	20.0	3	3
1974.90	4.55	.23	1.1	.4	83.1	4.5	3	3
1975.16	4.91	.08	.6	.7	82.7	14.5	1	1
1975.45	5.00	.08	1.4	.8	90.7	5.1	1	1
1975.63	5.13	.05	.4	.4	88.6	9.4	3	3
AVERAGES	5.17	.08	.4	.2	85.5	11.2	12	11

1502+10 (OR103) VARIABILITY INDEX= 3.2

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.71	.04					1	
1973.04	1.68	.03	4.0	1.0	6.8	3.0	2	2
1973.27	1.73	.02	2.2	.8	1.7	3.7	3	3
1973.41	1.92	.03	2.2	.8	12.7	6.4	3	2
1973.63	1.94	.03	2.6	.7	.9	2.9	3	3
1973.88	1.83	.04					1	
1974.16	1.75	.02	2.6	.8	6.7	3.7	3	3
1974.49	1.74	.03	3.1	.9	11.0	4.5	2	2
1974.90	1.92	.03	2.6	.6	20.1	5.5	3	3
1975.17	1.97	.05	1.4	1.2	179.0	9.6	1	1
1975.45	1.78	.03	1.7	1.2	12.7	13.2	2	1
1975.63	1.78	.03	2.6	.7	9.7	4.3	3	3
AVERAGES	1.81	.03	2.4	.2	8.4	2.6	12	10

1510-08 VARIABILITY INDEX= 9.2

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.20	.05					2	
1973.04	2.22	.05	.8	.6	56.7	45.3	2	2
1973.27	1.70	.04	2.5	.7	69.3	7.6	3	3
1973.40	1.46	.03	.3	1.3	86.3	31.4	3	3
1973.63	1.66	.04	4.8	1.3	85.8	2.2	3	3
1973.88	2.10	.07	2.6	1.6	87.3	5.0	1	1
1974.16	2.85	.05	3.1	.7	86.7	1.9	3	3
1974.49	3.22	.07	1.5	.5	75.3	6.7	2	2
1974.90	2.28	.06	1.9	.8	82.8	5.2	2	2
1975.17	2.23	.08	.5	1.1	96.5	26.2	1	1
1975.44	2.11	.04	1.6	1.0	92.0	6.2	3	2
1975.63	2.38	.05	4.0	.9	91.9	1.8	3	3
AVERAGES	2.20	.14	2.0	.4	84.3	6.0	12	11

1548+05 VARIABILITY INDEX= 6.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.98	.03					3	
1973.04	1.95	.02	1.6	.5	83.4	3.5	5	5
1973.26	1.98	.04	1.9	.3	85.4	2.2	6	6
1973.40	1.87	.01	2.1	.5	86.1	2.3	5	5
1973.63	2.00	.03	1.1	.3	77.1	5.6	5	5
1973.88	2.08	.03	2.0	.8	82.5	5.3	4	2
1974.16	2.08	.02	1.4	.4	89.6	3.4	6	6
1974.49	2.06	.02	1.5	.3	79.7	4.5	5	5
1974.90	2.20	.03	1.4	.3	79.9	4.7	6	6
1975.17	2.23	.03	1.9	.8	86.0	4.5	2	2
1975.45	2.35	.05	1.2	.5	81.6	6.4	4	4
1975.63	2.48	.04	.6	.2	37.5	12.1	6	5
AVERAGES	2.11	.05	1.5	.2	82.5	3.6	12	11

1555+00 VARIABILITY INDEX= 6.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.29	.03					4	
1973.04	1.33	.02	2.3	.8	104.6	5.9	5	5
1973.26	1.33	.02	3.4	.5	102.3	2.7	6	6
1973.40	1.23	.02	3.3	.9	97.7	4.0	4	4
1973.63	1.35	.02	3.2	.7	94.4	2.9	5	5
1973.88	1.41	.01	1.9	.6	90.1	3.6	4	4
1974.16	1.31	.02	2.7	.5	102.9	2.9	7	7
1974.49	1.26	.01	2.8	.5	101.0	2.7	5	5
1974.90	1.32	.01	2.4	.6	100.5	5.5	4	4
1975.17	1.46	.03	3.2	1.1	100.7	5.0	2	2
1975.45	1.65	.03	.9	.6	112.7	17.6	4	4
1975.63	1.63	.03	.9	.2	125.3	9.9	7	7
AVERAGES	1.38	.04	2.4	.3	100.7	3.3	12	11

1607+26 (CTD93) VARIABILITY INDEX= 1.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.21	.03					3	
1973.04	3.10	.03	.0	.3	33.7	90.0	3	3
1973.26	3.11	.03	.4	.5	3.6	16.1	3	3
1973.40	3.16	.04	.3	.3	38.5	56.4	2	2
1973.64	3.11	.04	.9	.8	7.9	13.0	2	1
1973.88	3.14	.03	.5	.5	2.4	10.5	3	3
1974.16	3.11	.04	.2	.3	153.2	43.6	4	4
1974.49	3.21	.03	1.8	.5	178.8	3.0	3	3
1974.90	3.05	.03	.2	.4	68.4	55.0	3	3
1975.15	3.11	.05	.7	.8	78.6	18.2	1	1
1975.45	3.16	.06	1.8	.8	84.6	5.7	1	1
1975.63	3.20	.03	.3	.5	12.0	24.6	3	3
AVERAGES	3.14	.01	0.0	.2	21.6	32.3	12	11

1611+34 (DA406) VARIABILITY INDEX= 2.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.58	.04					2	
1973.04	2.61	.04	1.9	1.0	1.3	5.6	2	1
1973.27	2.54	.03	1.0	.3	32.3	14.9	3	3
1973.41	2.59	.03	2.3	.5	14.9	4.2	3	3
1973.63	2.53	.03	3.2	.7	10.7	3.2	3	2
1973.88	2.62	.05	.9	.4	47.7	32.0	1	1
1974.16	2.63	.03	1.3	.3	54.4	16.1	3	2
1974.49	2.68	.04	2.7	.7	7.9	3.2	2	2
1974.90	2.52	.05	.8	.5	33.3	31.6	1	1
1975.17	2.66	.05	2.7	.9	9.4	4.9	1	1
1975.45	2.70	.03	2.0	.5	15.6	4.7	3	3
1975.63	2.77	.03	3.0	.5	7.7	2.3	3	3
AVERAGES	2.62	.02	1.7	.3	14.8	5.3	12	11

1616+36 VARIABILITY INDEX= 3.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.18	.04					1	
1973.04	1.01	.02					3	
1973.26	1.10	.02					3	
1973.41	.94	.03					2	
1973.63	.92	.03					2	
1973.88	.89	.02					3	
1974.16	.95	.02					4	
1974.49	.97	.02					3	
1974.90	.90	.02					3	
1975.16	.88	.04					1	
1975.45	.87	.04					1	
1975.63	.85	.02					3	
AVERAGES	.95	.02					12	

1624+41 (4C41.32) VARIABILITY INDEX= 2.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.69	.01					4	
1973.04	1.70	.01	.4	.7	109.0	41.0	4	4
1973.27	1.73	.01	.8	.8	2.6	8.4	4	4
1973.41	1.71	.02	.4	.7	1[illegible]2.6	31.4	4	4
1973.64	1.73	.02	1.3	1.1	175.7	7.1	3	3
1973.88	1.72	.01	.9	1.3	178.7	5.3	4	4
1974.16	1.72	.01	.7	1.2	3.7	9.0	6	6
1974.49	1.74	.02	1.3	1.2	172.6	8.5	5	4
1974.90	1.68	.02	.8	1.3	178.1	11.9	3	5
1975.17	1.68	.03	.7	1.0	85.2	15.7	2	2
1975.45	1.63	.02	.7	1.2	93.6	14.2	3	3
1975.63	1.60	.01	.3	.3	142.5	90.0	6	6
AVERAGES	1.69	.01	.3	.2	172.0	17.7	12	11

3C345 VARIABILITY INDEX= 3.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1973.04	9.48	.10	2.5	.3	66.8	3.4	2	2
1973.27	9.88	.08	2.6	.2	65.8	2.8	3	3
1973.41	9.98	.08	2.7	.2	67.9	2.5	3	3
1973.63	10.22	.09	2.2	.2	61.1	3.5	3	3
1973.88	10.38	.15	1.9	.3	57.5	7.6	1	1
1974.16	10.92	.09	2.4	.2	60.7	3.2	3	3
1974.49	10.62	.11	1.7	.2	53.7	6.1	2	2
1974.90	10.24	.10	2.5	.2	48.7	6.2	2	1
1975.17	10.59	.15	2.7	.3	59.2	5.1	1	1
1975.45	10.49	.09	2.5	.3	62.9	3.6	3	2
1975.63	10.24	.09	1.8	.2	49.7	5.9	3	2
AVERAGES	10.28	.12	2.3	.1	60.0	1.4	11	11

1656+05

VARIABILITY INDEX= 2.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.75	.01					4	
1973.04	1.75	.02	3.8	.5	17.0	2.6	5	5
1973.27	1.70	.02	3.2	.4	22.5	4.0	6	4
1973.41	1.58	.03	3.6	.5	16.9	2.8	5	5
1973.63	1.63	.02	3.6	.4	18.6	2.7	5	5
1973.88	1.73	.05	3.9	.3	17.6	1.9	4	4
1974.16	1.72	.02	4.4	.5	11.5	1.6	7	7
1974.49	1.65	.01	2.7	.3	23.0	3.2	5	5
1974.90	1.70	.03	3.0	.3	22.8	3.1	6	6
1975.17	1.60	.03	2.6	.6	29.6	10.1	2	2
1975.45	1.74	.03	2.3	.5	28.0	8.5	3	3
1975.63	1.68	.03	3.5	.4	15.7	2.3	6	5
AVERAGES	1.69	.02	3.3	.2	19.4	1.8	12	11

1722-02

VARIABILITY INDEX= 2.7

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.35	.02					4	
1973.04	1.41	.02	4.6	.7	107.8	3.5	5	5
1973.26	1.37	.01	4.8	.6	103.3	2.2	6	6
1973.41	1.34	.02	3.1	.7	110.8	6.1	4	4
1973.63	1.38	.02	5.5	.9	99.6	2.1	5	5
1973.88	1.41	.02	3.8	.8	104.0	3.4	4	4
1974.16	1.33	.03	5.0	.9	102.9	3.1	3	3
1974.49	1.31	.01	4.5	.6	105.[illegible]	2.4	5	5
1974.90	1.27	.03	3.3	.5	101.1	3.0	6	6
1975.17	1.31	.04	3.1	1.7	98.0	7.3	1	1
1975.45	1.22	.02	3.7	1.0	100.3	4.5	3	3
1975.63	1.28	.02	4.5	.6	101.4	2.3	6	6
AVERAGES	1.33	.02	4.1	.2	103.0	1.6	12	11

1730-13 (NRAO530) VARIABILITY INDEX= 4.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	4.29	.05					4	
1973.04	4.53	.07	4.1	.4	12.2	1.6	5	5
1973.27	4.67	.03	1.6	.1	48.5	6.1	5	4
1973.40	4.49	.06	1.6	.2	36.0	8.0	4	3
1973.63	4.66	.06	2.2	.8	16.8	7.1	4	4
1974.17	4.69	.11	1.7	.2	41.1	6.7	3	3
1974.49	5.18	.08	1.5	.1	32.2	3.7	5	5
1974.90	4.96	.05	1.9	.2	55.5	4.2	6	6
1975.45	5.18	.12	1.5	.2	32.6	6.9	3	3
1975.63	5.16	.04	1.7	.1	52.8	4.3	6	6
AVERAGES	4.78	.10	1.7	.2	32.9	3.3	10	9

1741-03 VARIABILITY INDEX= 8.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.58	.07					1	
1973.04	2.36	.04	1.3	1.0	83.3	8.1	2	2
1973.27	2.36	.04	.4	.6	103.5	24.1	3	3
1973.41	2.08	.03	1.2	.6	75.6	9.7	3	3
1973.63	2.31	.04	2.8	.8	86.8	3.0	2	2
1973.88	2.26	.06	2.0	.9	72.7	10.2	1	1
1974.17	2.25	.04	2.3	.7	74.1	5.9	2	2
1974.49	1.70	.04	2.7	.9	81.2	4.7	2	2
1974.90	1.87	.03	1.4	.6	70.7	10.5	3	3
1975.45	1.72	.03	2.2	1.0	76.9	17.2	3	3
1975.63	1.57	.03	2.4	.8	74.5	6.5	3	3
AVERAGES	2.10	.10	1.8	.2	78.3	3.5	11	10

1749+09 (OT081) VARIABILITY INDEX= 8.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.00	.00					4	
1973.04	1.01	.00					5	
1973.27	.93	.02					5	
1973.41	.89	.01					5	
1973.63	.75	.02					3	
1973.88	.79	.02					3	
1974.16	.75	.02					4	
1974.49	.93	.02					5	
1974.90	1.07	.02					6	
1975.17	1.04	.04					1	
1975.45	1.21	.02					4	
1975.63	1.13	.02					5	
AVERAGES	.96	.04					12	

3C371 VARIABILITY INDEX= 1.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.21	.05					1	
1973.04	2.32	.03	2.4	.7	9.2	4.3	2	2
1973.27	2.20	.03	3.0	1.1	7.6	4.8	3	1
1973.41	2.29	.03	1.6	.7	9.0	6.3	2	2
1973.64	2.12	.03	2.5	.8	7.2	4.2	2	2
1973.88	2.30	.05	1.8	1.0	8.6	6.0	1	1
1974.16	2.20	.03	1.8	1.1	10.6	9.2	2	1
1974.49	2.21	.03	2.8	1.1	5.6	4.6	2	1
1974.90	2.23	.11	2.7	.6	8.4	3.1	3	3
1975.45	2.15	.03	1.7	.7	15.4	8.4	3	2
1975.63	2.14	.03	1.8	.6	9.8	5.2	3	3
AVERAGES	2.22	.02	2.2	.2	8.7	2.2	11	10

3C380 VARIABILITY INDEX= 2.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	9.41	.14					1	
1973.04	9.81	.10	1.2	.4	8.2	4.5	2	2
1973.27	9.72	.08	.7	.3	9.6	6.8	3	3
1973.41	9.75	.10	.9	.4	7.3	5.6	2	2
1973.63	9.49	.10	2.0	.4	4.4	2.3	2	2
1973.88	9.57	.14	1.6	.5	9.3	5.0	1	1
1974.17	9.67	.10	1.2	.4	9.1	4.6	2	2
1974.49	9.47	.10	1.5	.4	5.0	3.1	2	2
1974.90	9.50	.08	1.4	.3	20.4	4.7	3	3
1975.45	9.28	.08	.3	.1	42.9	30.8	3	3
1975.63	9.21	.08	.4	.2	21.8	15.4	3	3
AVERAGES	9.53	.06	1.1	.2	10.1	4.6	11	10

3C390.3 VARIABILITY INDEX= 1.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	6.49	.10					2	
1973.04	6.69	.08	4.6	.2	29.3	1.9	3	3
1973.27	6.50	.10	4.8	.2	32.4	2.3	2	2
1973.41	7.03	.15	3.6	.2	40.0	4.4	1	1
1973.63	6.74	.10	4.3	.2	43.4	2.8	2	2
1973.88	6.72	.10	5.2	.3	22.9	1.8	2	2
1974.16	6.86	.10	3.6	.2	38.2	3.3	2	2
1974.49	6.70	.08	3.8	.2	53.5	2.5	3	3
1974.90	7.05	.35	5.9	.4	16.0	1.3	2	2
1975.16	6.72	.14	4.1	.5	23.6	3.5	1	1
1975.49	6.84	.15	4.1	.5	24.8	3.5	1	1
1975.62	6.71	.07	3.8	.1	26.4	.8	4	4
AVERAGES	6.75	.05	4.1	.3	30.7	1.9	12	11

2005+40

VARIABILITY INDEX= 3.0

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1975.45	3.93	.04	2.0	.3	114.6	4.9	3	3
1975.63	4.07	.03	2.1	.3	112.0	3.8	5	5
AVERAGES	4.00	.07	2.1	.1	113.3	.9	2	2

3C418

VARIABILITY INDEX= 3.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.88	.06					1	
1973.04	3.89	.05	1.7	.3	124.5	6.8	2	2
1973.27	4.14	.04	1.8	.3	117.7	5.7	3	3
1973.41	4.12	.04	1.8	.3	115.1	6.2	3	3
1973.63	3.89	.04	2.5	.3	115.6	4.6	3	3
1973.88	3.73	.04	2.5	.4	111.1	4.7	2	2
1974.17	4.42	.05	2.1	.5	107.1	4.8	2	2
1974.49	4.00	.05	2.9	.5	105.6	3.5	2	2
1974.90	4.43	.22	2.8	.3	108.5	2.9	3	3
1975.45	4.13	.04	2.5	.4	107.3	3.1	3	3
1975.63	4.19	.04	2.7	.6	105.4	4.1	3	2
1975.63	4.33	.05	2.7	.6	105.6	4.2	2	2
AVERAGES	4.10	.07	2.3	.1	110.3	1.8	12	11

2053+36 (DA529) VARIABILITY INDEX= 3.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1973.04	4.58	.07	.2	.3	12.7	19.8	4	5
1973.26	4.47	.04	.3	.3	33.8	39.1	3	2
1973.41	4.32	.04	.4	.3	14.2	13.7	5	5
1973.63	4.29	.09	.3	.2	163.9	17.8	4	4
1974.16	4.48	.04	1.4	.4	175.6	3.4	3	3
1973.88	4.37	.02	.3	.2	169.5	10.8	5	5
1974.50	4.64	.06	.3	.7	.5	29.1	4	1
1974.90	4.82	.04	.5	.3	87.8	9.6	6	5
1975.17	4.57	.07	.3	.7	89.6	23.8	1	1
1975.45	4.79	.07	1.1	.7	92.7	3.8	4	4
1975.63	4.72	.05	.4	.2	107.0	11.5	7	7
AVERAGES	4.55	.06	0.0	.2	173.2	82.8	11	11

2113+29 VARIABILITY INDEX= 4.8

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	.89	.01					4	
1973.04	1.05	.01	1.6	1.0	86.3	7.7	5	5
1973.26	1.22	.02	.8	1.1	180.0	14.9	3	3
1973.41	1.16	.05	1.4	1.0	86.5	6.5	4	4
1973.63	1.20	.01	2.4	1.4	17.6	11.9	5	5
1973.88	1.08	.02	.5	.5	39.5	65.8	5	3
1974.16	1.09	.03	1.5	1.1	80.4	10.7	4	3
1974.49	.89	.02	2.9	1.4	174.4	5.9	3	3
1974.90	.97	.02	.7	.7	53.9	43.5	5	5
1975.17	1.03	.04	3.9	2.2	3.0	6.2	1	1
1975.45	1.06	.02	1.2	1.0	161.4	20.4	3	3
1975.63	1.00	.02	1.3	.4	132.2	30.9	6	6
AVERAGES	1.05	.03	.1	.5	6.2	28.0	12	11

2134+00 VARIABILITY INDEX= 2.5

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	6.98	.07					3	
1973.04	7.32	.15	.1	.3	92.2	34.6	5	5
1973.26	7.01	.11	.6	.1	154.0	6.7	4	4
1973.41	6.75	.03	.4	.1	142.3	14.9	5	5
1973.63	7.06	.03	.2	.1	112.5	15.3	4	4
1973.88	7.15	.06	.2	.1	147.6	17.1	4	4
1974.16	7.23	.12	.1	.1	114.1	34.3	4	4
1974.49	6.56	.07	.3	.1	133.0	32.9	3	3
1974.90	7.23	.06	.4	.2	112.5	12.7	5	5
1975.17	7.00	.13	.6	.2	133.5	27.6	1	1
1975.45	6.89	.12	.3	.2	92.1	10.9	4	4
1975.63	6.99	.06	.1	.1	142.3	36.5	7	7
AVERAGES	7.01	.06	.2	.1	130.8	6.8	12	11

2145+06 VARIABILITY INDEX= 2.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.35	.02					4	
1973.04	3.30	.05	.1	.1	42.3	72.7	5	5
1973.26	3.28	.04	.3	.2	168.9	11.1	4	4
1973.41	3.18	.03	.5	.3	102.0	9.6	5	5
1973.64	3.21	.02	.1	.2	110.7	42.5	5	5
1973.88	3.27	.05	.4	.2	80.1	19.9	5	5
1974.16	3.35	.04	.4	.4	103.0	17.5	3	3
1974.49	3.17	.02	.5	.2	100.2	7.7	5	5
1974.90	3.20	.01	.3	.2	83.4	17.3	5	5
1975.17	3.13	.06	.4	.5	61.2	60.5	1	1
1975.45	3.12	.06	.6	.2	78.4	8.6	4	4
1975.63	3.09	.03	.2	.2	77.3	18.1	7	7
AVERAGES	3.22	.03	.2	.1	87.7	8.9	12	11

BL LAC (VRO4222) VARIABILITY INDEX= 29.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	6.02	.05					3	
1973.04	4.41	.04	2.5	.4	2.3	1.8	3	3
1973.26	4.01	.04	3.3	.4	179.1	1.4	4	3
1973.40	4.83	.05	.8	.6	167.6	13.1	2	1
1973.64	6.90	.07	1.6	.4	99.1	3.6	2	2
1973.88	7.13	.06	1.4	.3	109.0	4.8	3	3
1974.16	5.62	.06	.3	.4	14.7	26.4	2	2
1974.49	6.03	.05	3.2	.4	93.3	1.3	3	3
1974.90	5.37	.06	5.7	.4	100.7	1.2	2	2
1975.17	2.68	.05	2.6	.8	109.7	7.3	1	1
1975.45	2.84	.05	2.5	.9	99.2	5.3	1	1
1975.63	2.97	.03	2.7	.4	115.1	5.3	3	3
AVERAGES	4.90	.45	1.1	.6	109.4	14.2	12	11

2201+31 (4C31.63) VARIABILITY INDEX= 6.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.34	.05					1	
1973.04	2.37	.03	.4	.4	148.7	53.4	2	2
1973.27	2.18	.05	1.1	.7	150.2	26.9	1	1
1973.41	2.40	.03	.6	.7	153.6	40.9	3	1
1973.64	2.24	.03	1.0	.5	110.3	12.7	3	3
1973.87	2.03	.03	.3	.5	128.3	90.0	2	1
1974.17	1.90	.03	1.1	.8	106.5	14.5	2	2
1974.49	1.86	.03	1.7	.7	159.5	11.2	2	2
1974.90	1.99	.03	1.0	.5	111.1	14.1	3	3
1975.45	1.93	.03	1.3	.5	116.8	13.8	3	3
1975.63	2.31	.03	1.3	2.5	140.9	18.7	3	3
AVERAGES	2.14	.06	.7	.1	132.3	4.1	11	10

2216-03 VARIABILITY INDEX= 2.7

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.21	.03					3	
1973.04	1.35	.03	1.1	1.5	92.7	9.8	3	3
1973.26	1.22	.03	1.0	1.0	101.0	16.1	3	3
1973.41	1.20	.03	1.8	1.7	112.4	26.5	2	1
1973.63	1.24	.03	3.2	2.2	90.2	6.1	2	1
1973.88	1.33	.03	2.7	1.0	4.0	4.1	3	3
1974.16	1.26	.03	.9	1.2	100.3	20.8	2	2
1974.49	1.29	.03	1.8	.9	102.3	8.6	3	3
1974.90	1.29	.03	2.7	1.0	94.8	4.3	3	3
1975.17	1.41	.05	1.1	1.6	91.5	15.9	1	1
1975.45	1.39	.05	.5	1.6	7.6	47.5	1	1
1975.63	1.45	.02	2.5	.8	91.0	3.5	4	4
AVERAGES	1.30	.02	1.0	.5	96.8	12.0	12	11

3C446 VARIABILITY INDEX= 2.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	4.81	.02					4	
1973.04	4.95	.22	6.5	.5	174.5	.6	5	5
1973.26	4.78	.08	5.9	.2	173.2	.6	5	5
1973.41	4.67	.10	6.0	.5	174.3	.6	5	5
1973.64	4.58	.01	8.5	.4	174.6	.4	5	5
1973.88	4.67	.14	6.3	.3	173.0	.6	5	5
1974.17	4.80	.07	4.9	.4	172.5	1.0	3	3
1974.49	4.54	.06	4.8	.2	172.0	.7	5	5
1974.90	4.51	.06	3.3	.3	167.1	2.1	6	6
1975.17	4.49	.11	4.2	.7	170.4	2.3	1	1
1975.45	4.33	.05	3.4	.3	169.0	1.4	4	4
1975.63	4.35	.03	4.2	.2	170.3	.8	7	7
AVERAGES	4.62	.06	5.2	.5	172.5	2.5	12	11

CTA102 VARIABILITY INDEX= 1.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	4.65	.01					4	
1973.04	4.59	.09	5.3	.2	13.7	.9	5	5
1973.26	4.66	.03	5.2	.1	13.9	.5	5	5
1973.40	4.58	.05	5.5	.3	11.6	.7	4	4
1973.64	4.81	.01	5.0	.2	11.9	.7	4	4
1973.88	4.62	.06	4.6	.2	9.3	.6	4	4
1974.16	4.76	.07	5.0	.2	11.8	1.6	4	4
1974.49	4.66	.01	4.7	.1	11.1	.6	5	5
1974.90	4.68	.02	4.0	.1	14.3	1.1	6	6
1975.17	4.72	.08	3.7	.6	14.9	3.2	1	1
1975.45	4.73	.04	3.9	.1	13.1	1.0	4	4
1975.63	4.78	.02	4.1	.2	11.3	.7	7	7
AVERAGES	4.70	.02	4.6	.2	12.4	1.1	12	11

2243-12 (OY-172.6) VARIABILITY INDEX= 2.5

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	2.49	.02					4	
1973.04	2.55	.06	2.6	1.8	1.9	2.7	3	3
1973.26	2.48	.10	4.7	.9	179.1	.9	5	5
1973.40	2.44	.06	3.6	1.9	174.1	3.7	3	3
1973.64	2.51	.02	8.7	.8	177.3	.6	5	5
1973.88	2.48	.03	5.1	.7	177.6	.9	4	4
1974.17	2.26	.05	4.3	.9	166.4	4.6	3	3
1974.49	2.64	.05	2.6	.5	170.5	2.6	4	4
1974.90	2.67	.04	2.2	.7	172.8	3.1	5	5
1975.45	2.56	.03	1.4	.6	167.4	7.3	4	4
1975.64	2.54	.02	3.0	1.3	174.2	3.1	6	5
AVERAGES	2.51	.03	3.7	.6	175.0	5.0	11	10

3C454.3

VARIABILITY INDEX= 3.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	10.73	.03					4	
1973.04	10.78	.14	6.2	.1	170.6	.6	5	5
1973.26	10.81	.06	6.2	.1	168.4	.4	5	5
1973.40	10.68	.06	6.5	.2	169.2	.6	4	4
1973.64	10.92	.03	6.0	.2	168.8	.5	5	5
1973.88	10.32	.06	6.2	.1	169.2	.8	5	5
1974.16	10.56	.11	6.9	.2	170.7	1.0	4	4
1974.49	10.31	.07	6.6	.2	167.6	.5	5	5
1974.90	10.47	.05	5.2	.1	165.6	.5	6	6
1975.17	10.37	.15	5.2	.5	165.1	2.0	1	1
1975.45	11.08	.13	5.0	.1	167.4	.7	4	4
1975.63	11.06	.06	5.7	.2	167.7	.5	7	7
AVERAGES	10.67	.08	6.0	.2	168.4	.9	12	11

2345-16

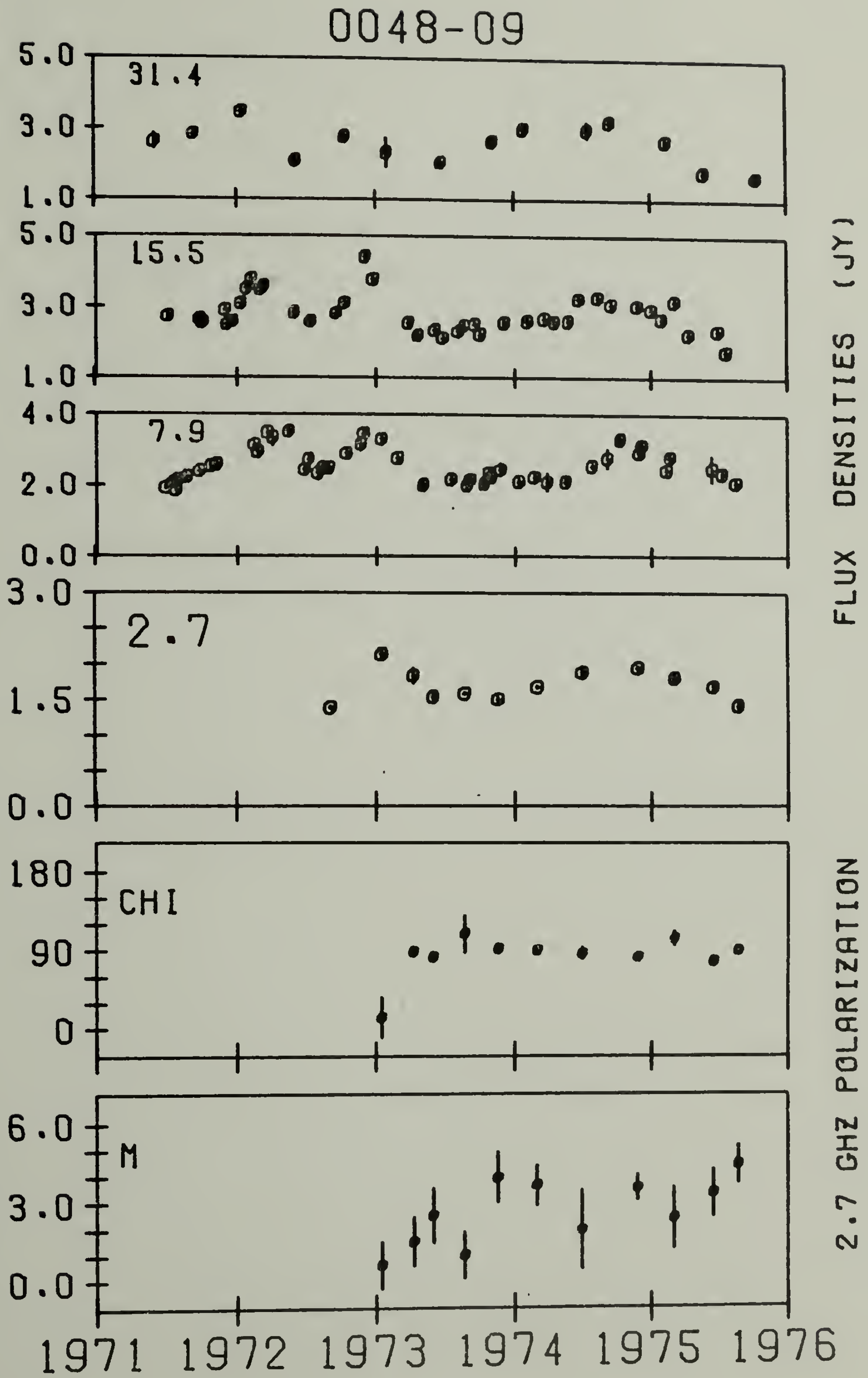
VARIABILITY INDEX= 3.9

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.30	.02					4	
1973.04	4.06	.12	.9	.9	163.6	18.1	3	3
1973.26	3.79	.15	.4	.5	151.6	51.2	4	4
1973.41	3.99	.10	.6	1.8	90.4	13.2	4	2
1973.64	4.23	.05	2.1	1.7	3.1	3.2	4	4
1973.88	4.16	.04	.4	.3	55.9	44.7	5	4
1974.16	4.34	.14	1.8	.5	83.5	3.5	5	5
1974.49	4.13	.07	.3	.3	167.2	15.1	5	5
1974.90	3.70	.03	2.8	.5	91.2	2.3	6	5
1975.17	3.73	.20					1	
1975.45	4.17	.15	.5	.5	14.1	20.1	2	2
1975.63	4.18	.04	1.0	.2	66.9	6.6	7	7
AVERAGES	3.95	.10	0.3	.4	79.1	49.5	12	10

APPENDIX II

GRAPHICAL PRESENTATION OF VARIABLE SOURCE DATA

This appendix shows plots for variable sources whose tabular data is listed in Appendix I. Sources with only a few data points have not been plotted.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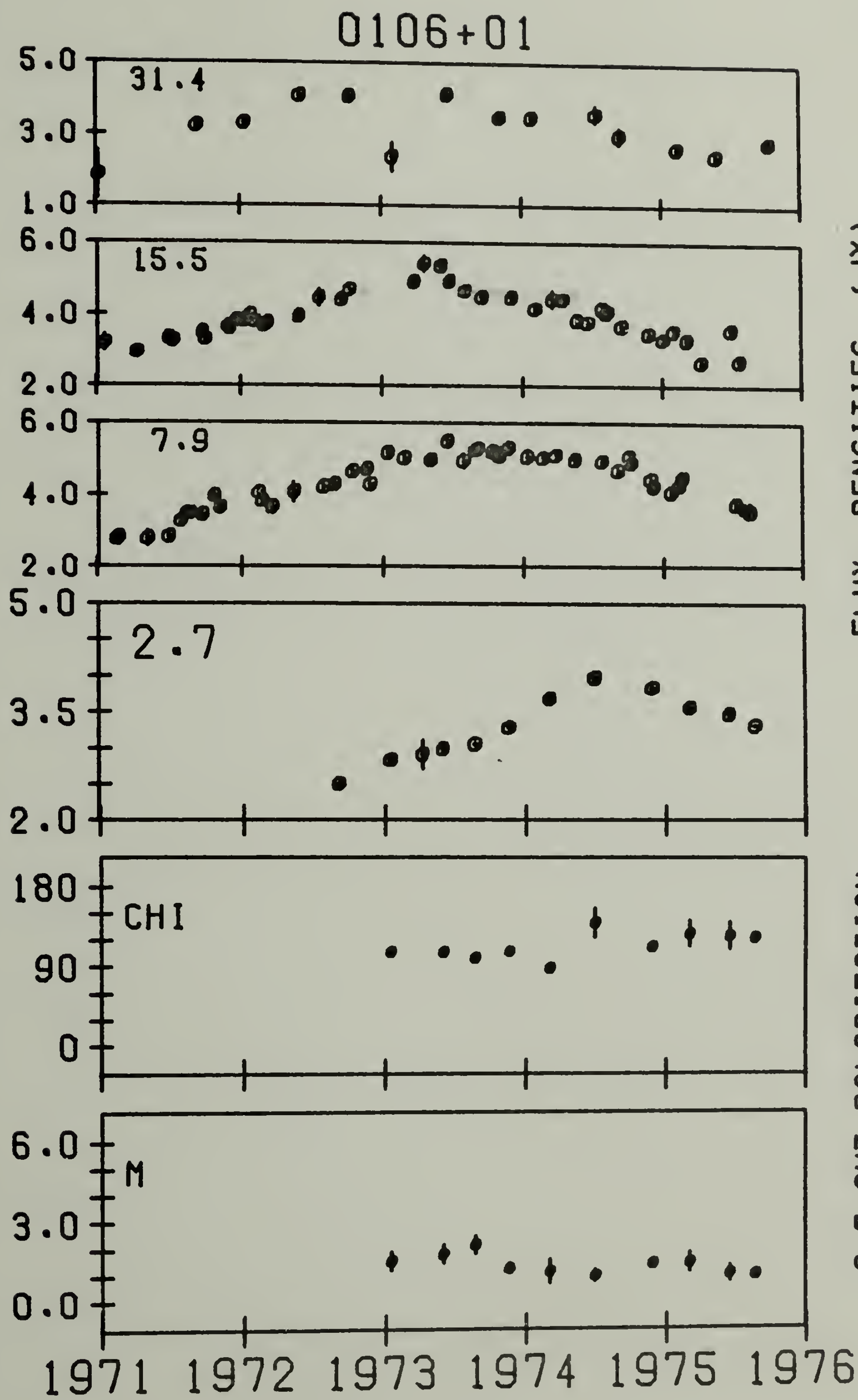
15.5
7.9
2.7
CHI
M
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
5.0
3.0
1.0
4.0
2.0
0.0
1.5
180
90
0
6.0
1971
1972
1973
1974
1975
1976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CHI
M
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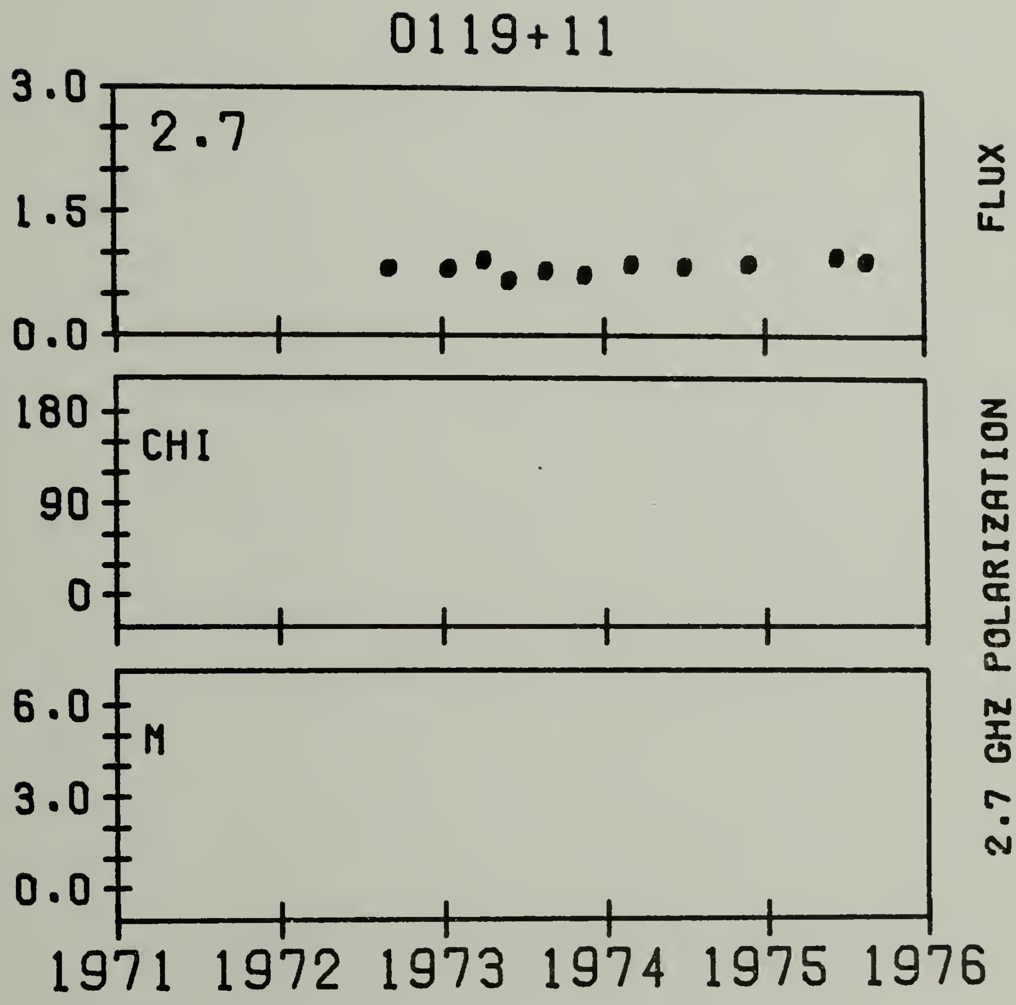
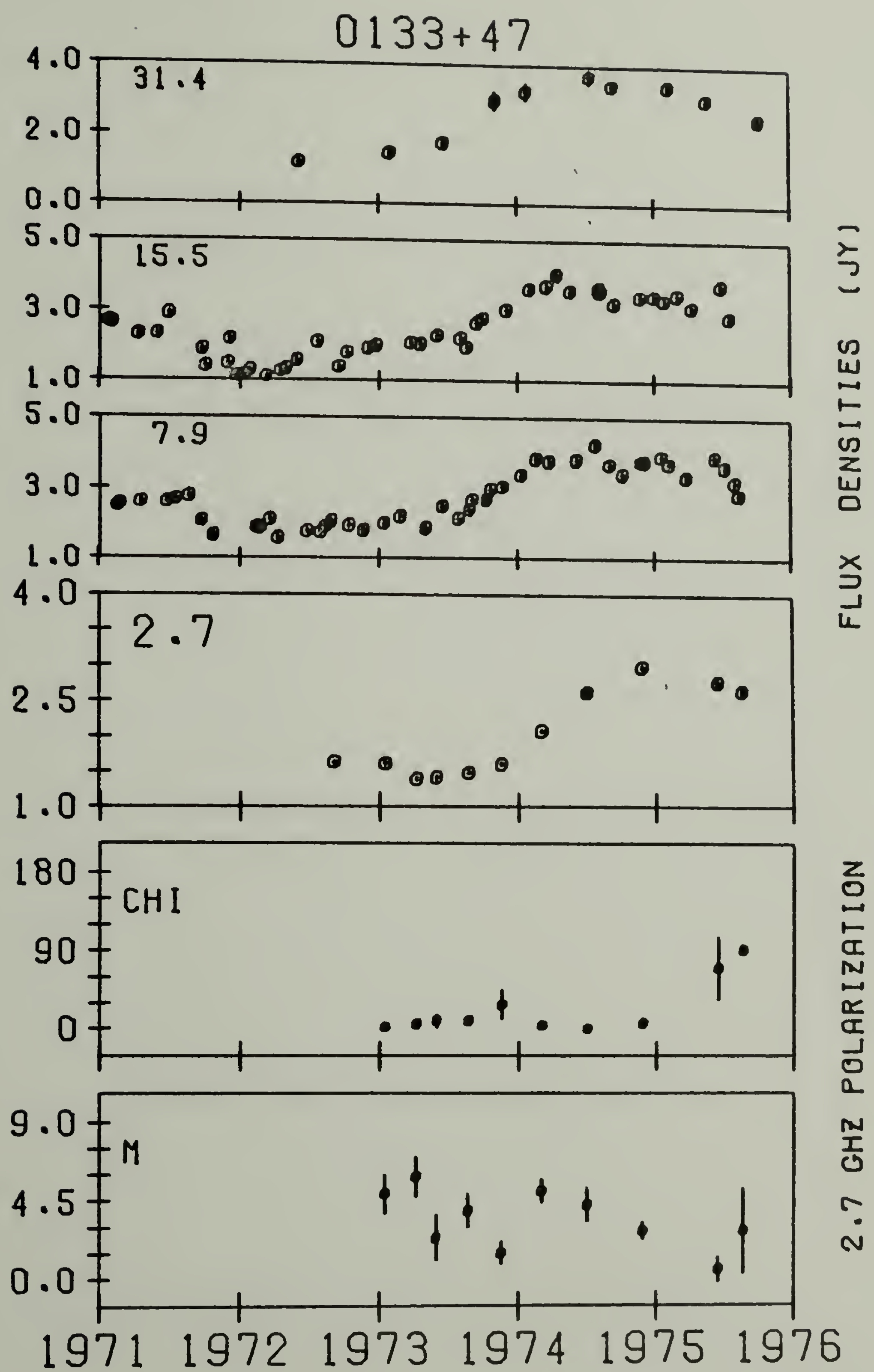
2.0
6.0
4.0
2.0
5.0
3.5
2.0
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION



0119+11
3.0
2.7
1.5
0.0
FLUX
180
CHI
90
0
6.0
M
3.0
0.0
2.7 GHZ POLARIZATION
1971 1972 1973 1974 1975 1976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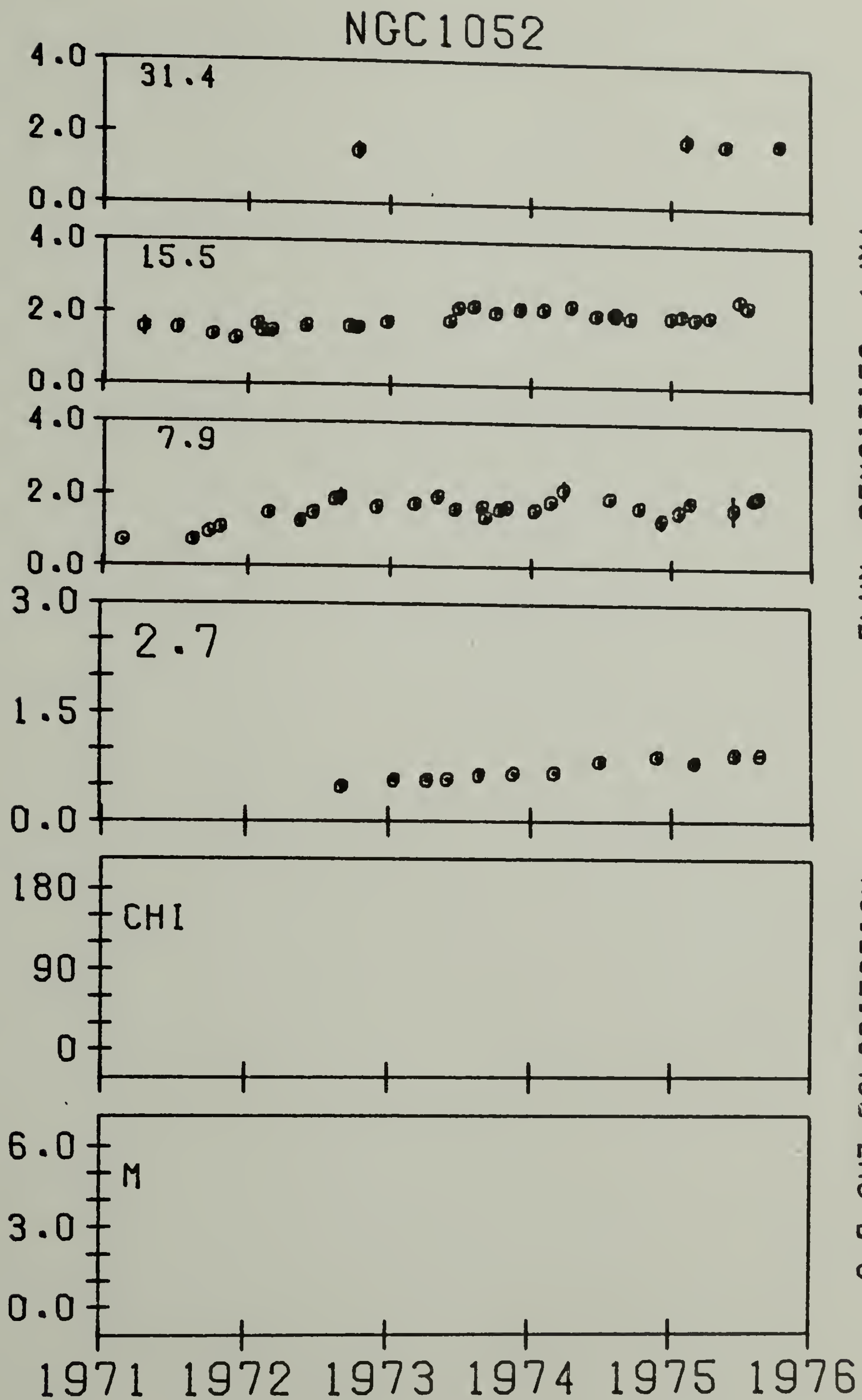
2.0
0.0
5.0
3.0
1.0
5.0
3.0
1.0
4.0
2.5
1.0
180
90
0
9.0
4.5
0.0
1971
1972
1973
1974
1975
1976


NGC1052
31.4
15.5
7.9
2.7
CHI
M
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2.0
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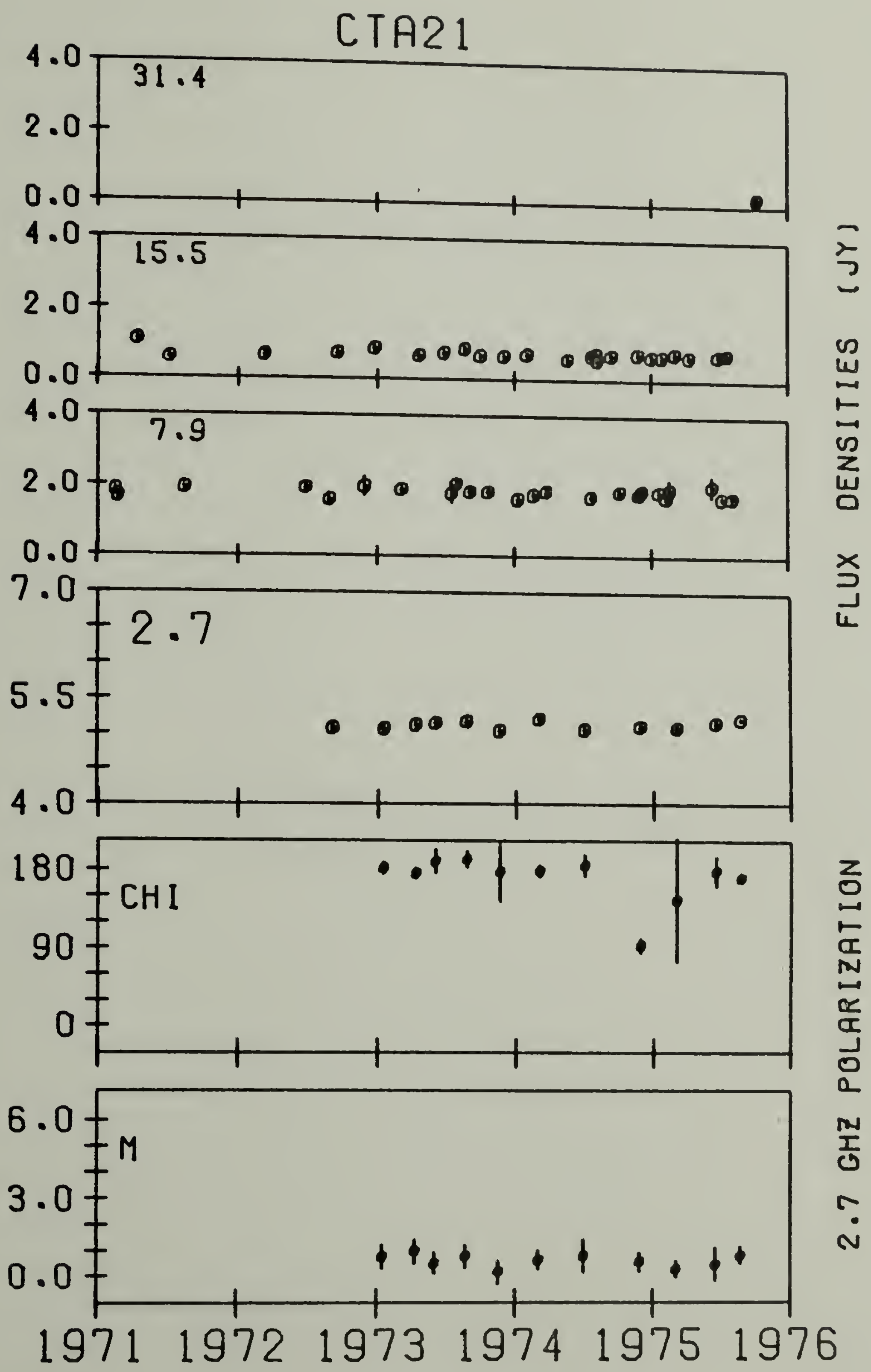
3.0
1.5
180
90
0
6.0
3.0
1971 1972 1973 1974 1975 1976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15.5
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CHI
M
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2.0
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7.0
5.5
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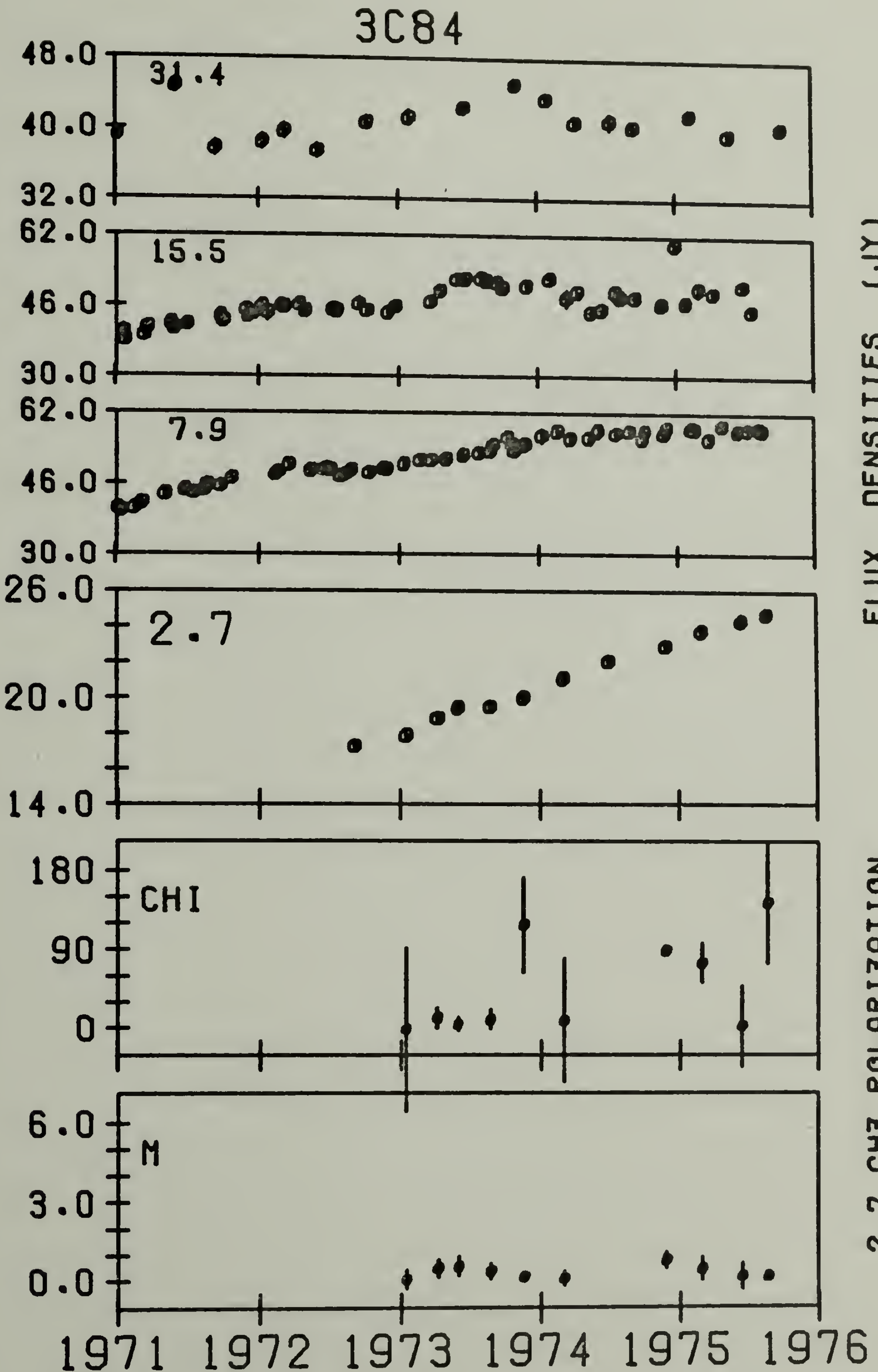
90
0
6.0
3.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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CHI
M
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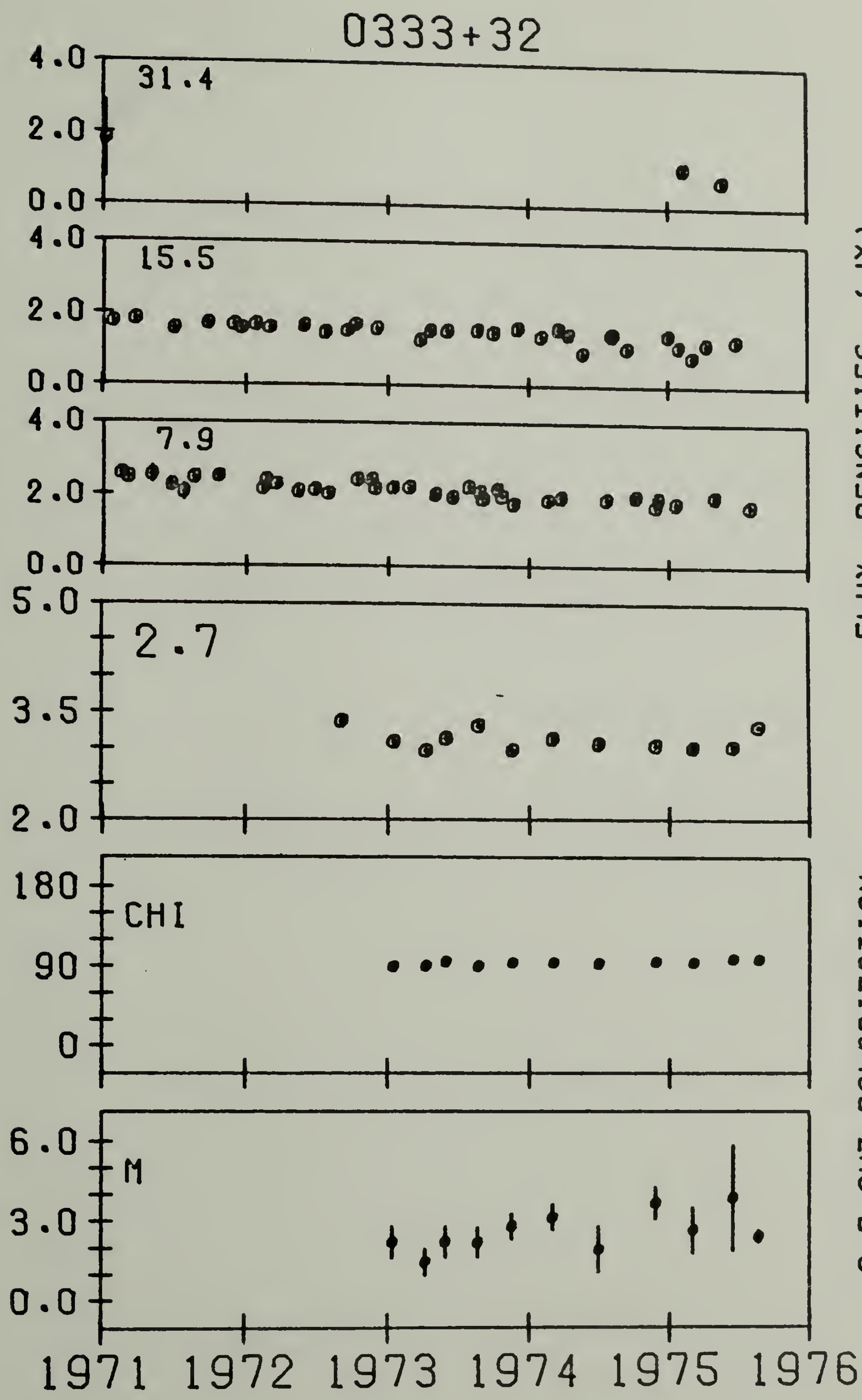
40.0
32.0
62.0
46.0
30.0
62.0
46.0
30.0
26.0
20.0
14.0
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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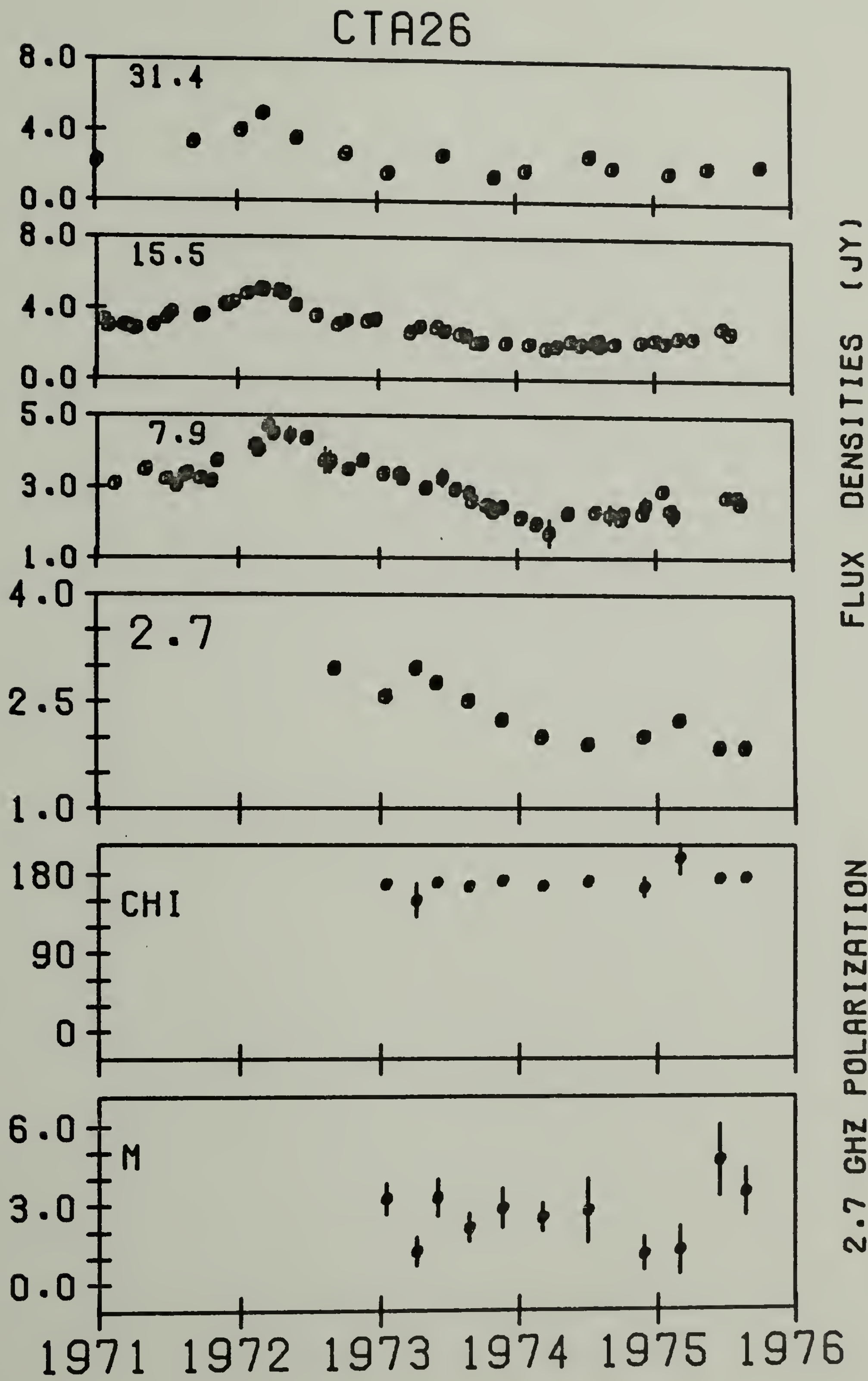
31.4
15.5
7.9
2.7
CHI
M
4.0
2.0
0.0
5.0
3.5
180
90
0
6.0
3.0
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
1971
1972
1973
1974
1975
1976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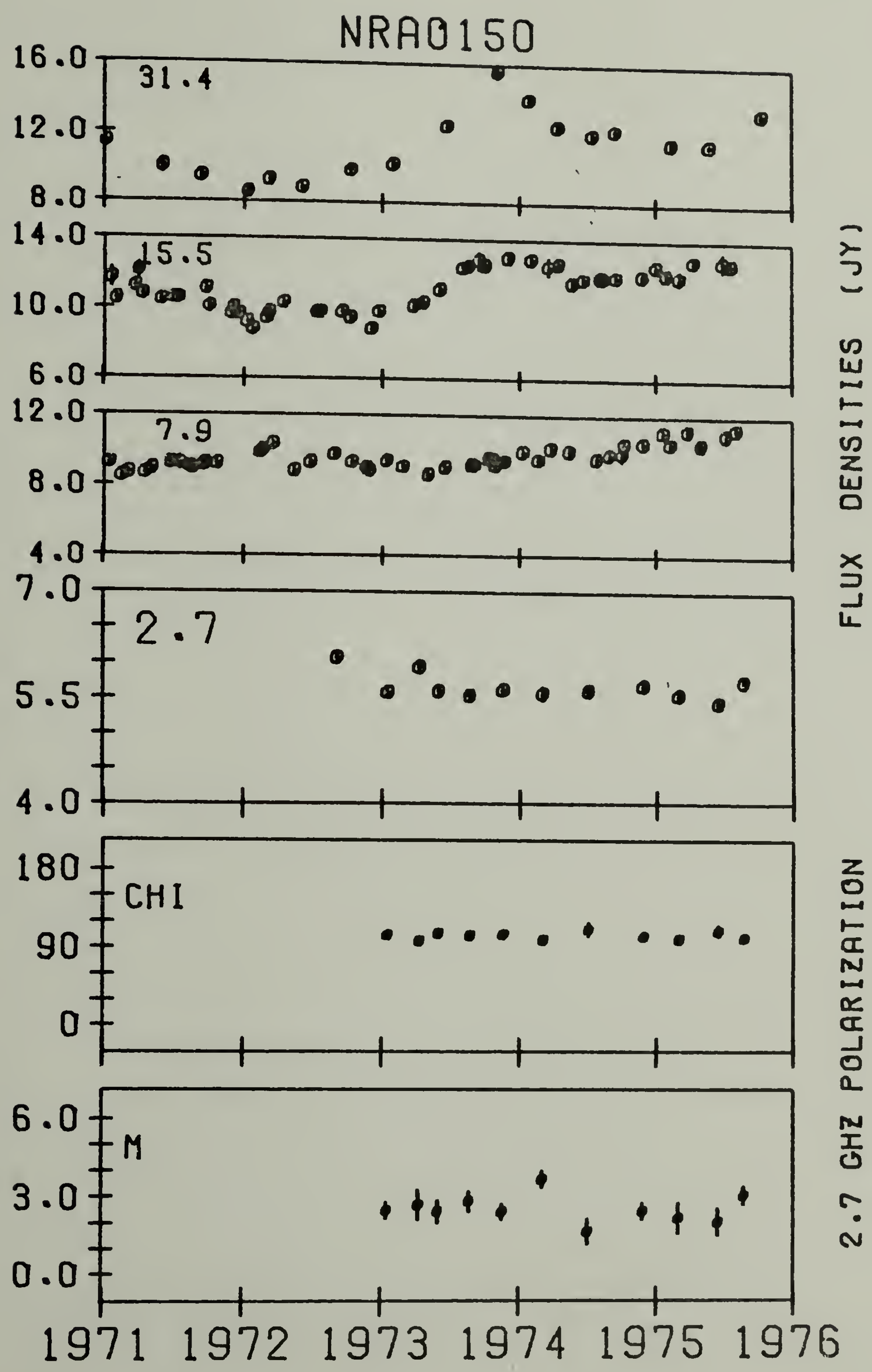
5.0
3.0
1.0
2.5
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION


NRAO150
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7.9
2.7
CHI
M
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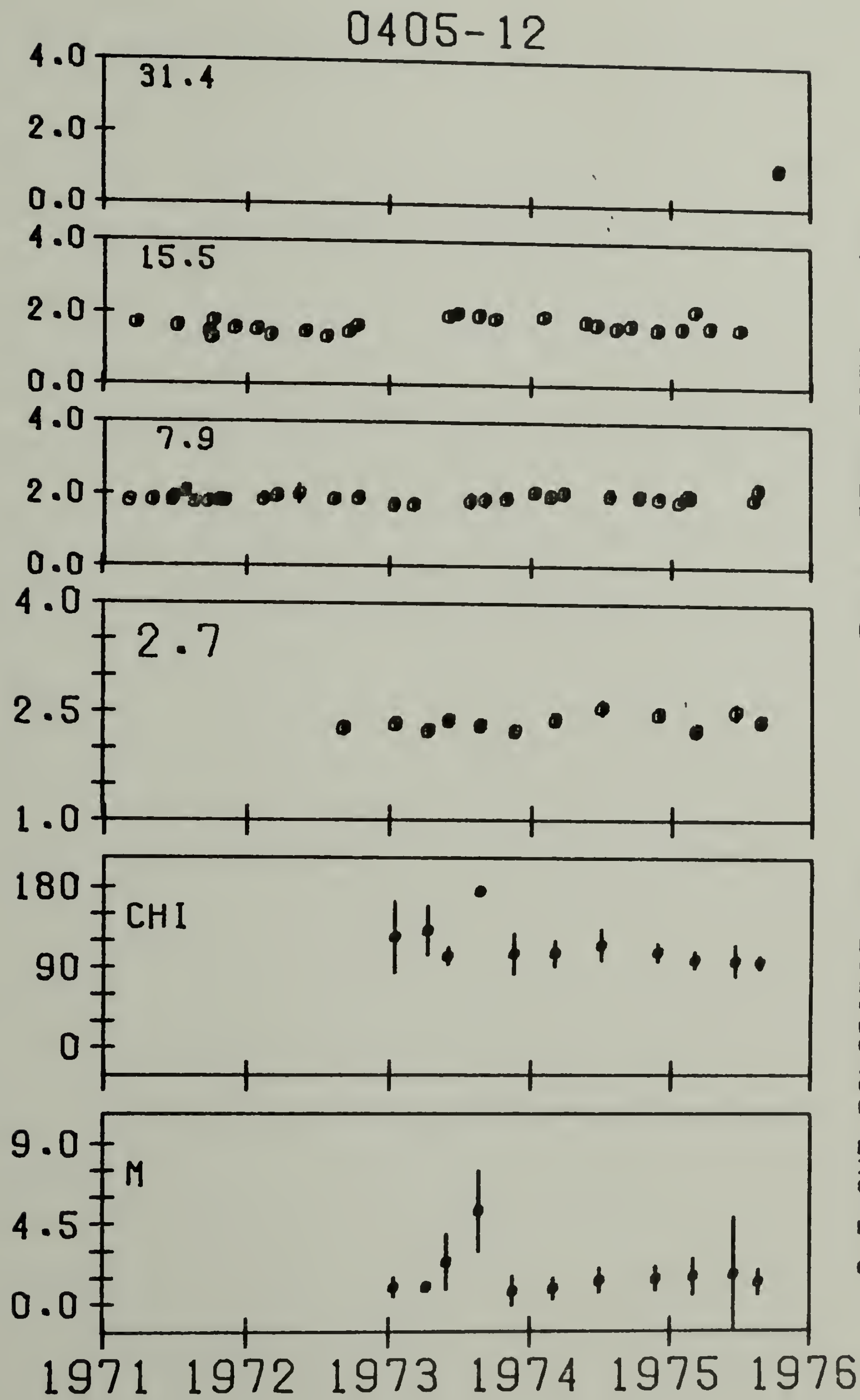
12.0
8.0
14.0
10.0
6.0
12.0
8.0
4.0
7.0
5.5
4.0
180
90
0
6.0
3.0
0.0
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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2.7
CHI
M
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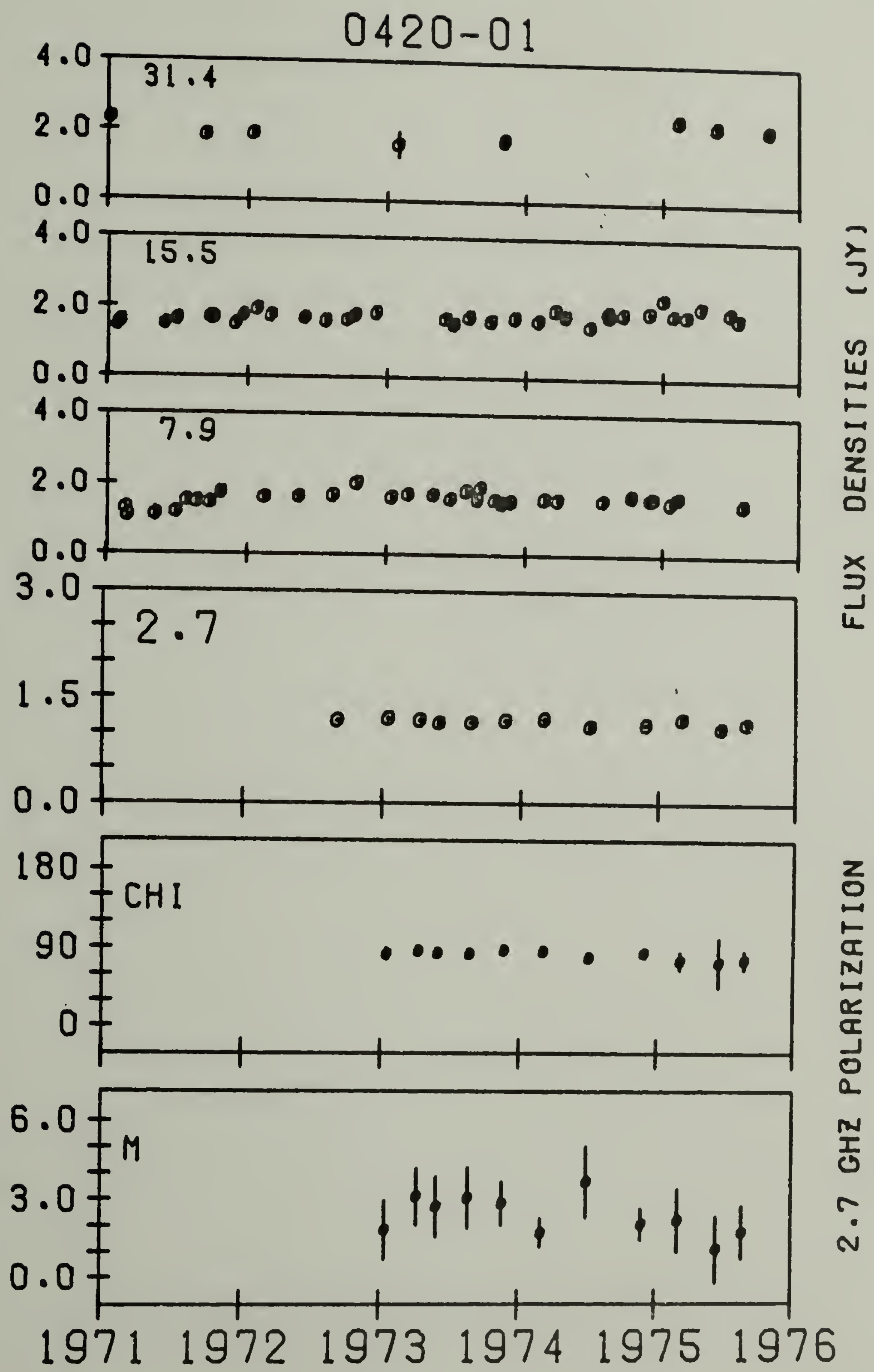
2.0
0.0
2.5
1.0
180
90
0
9.0
4.5
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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CHI
M
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2.0
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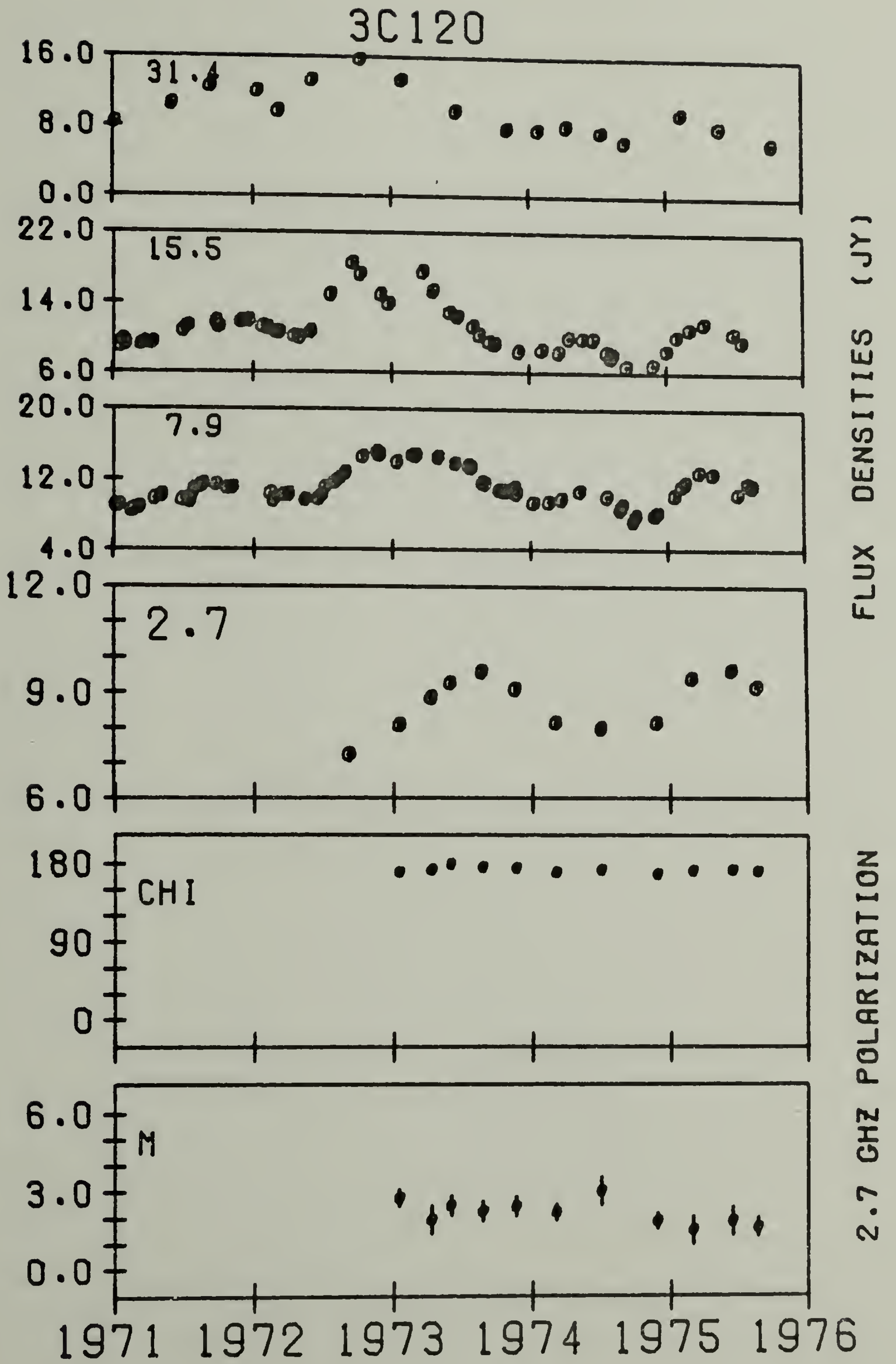
3.0
1.5
180
90
0
6.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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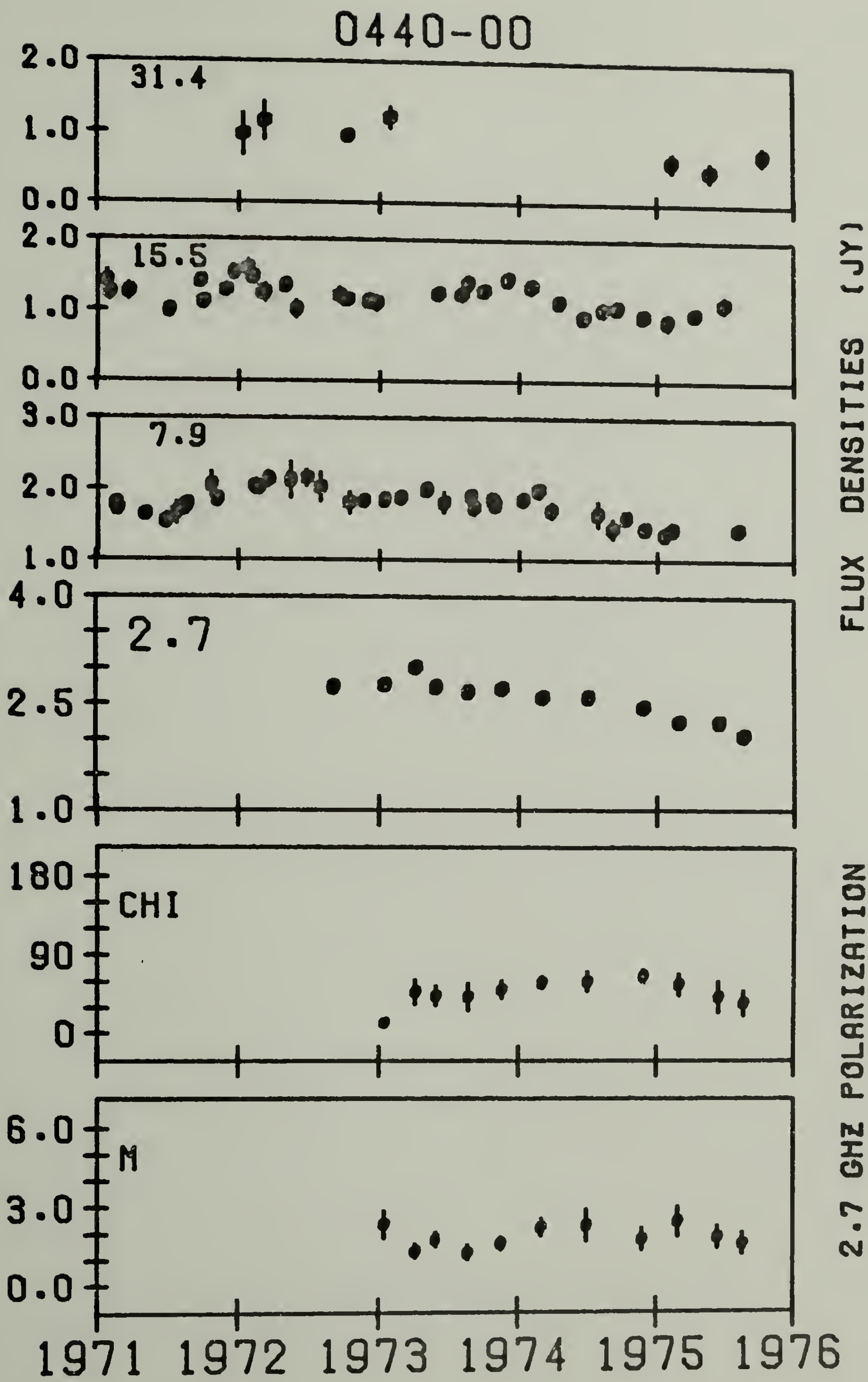
7.9
2.7
CHI
M
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
1971 1972 1973 1974 1975 1976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7.9
2.7
CHI
M
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2.7 GHZ POLARIZATION
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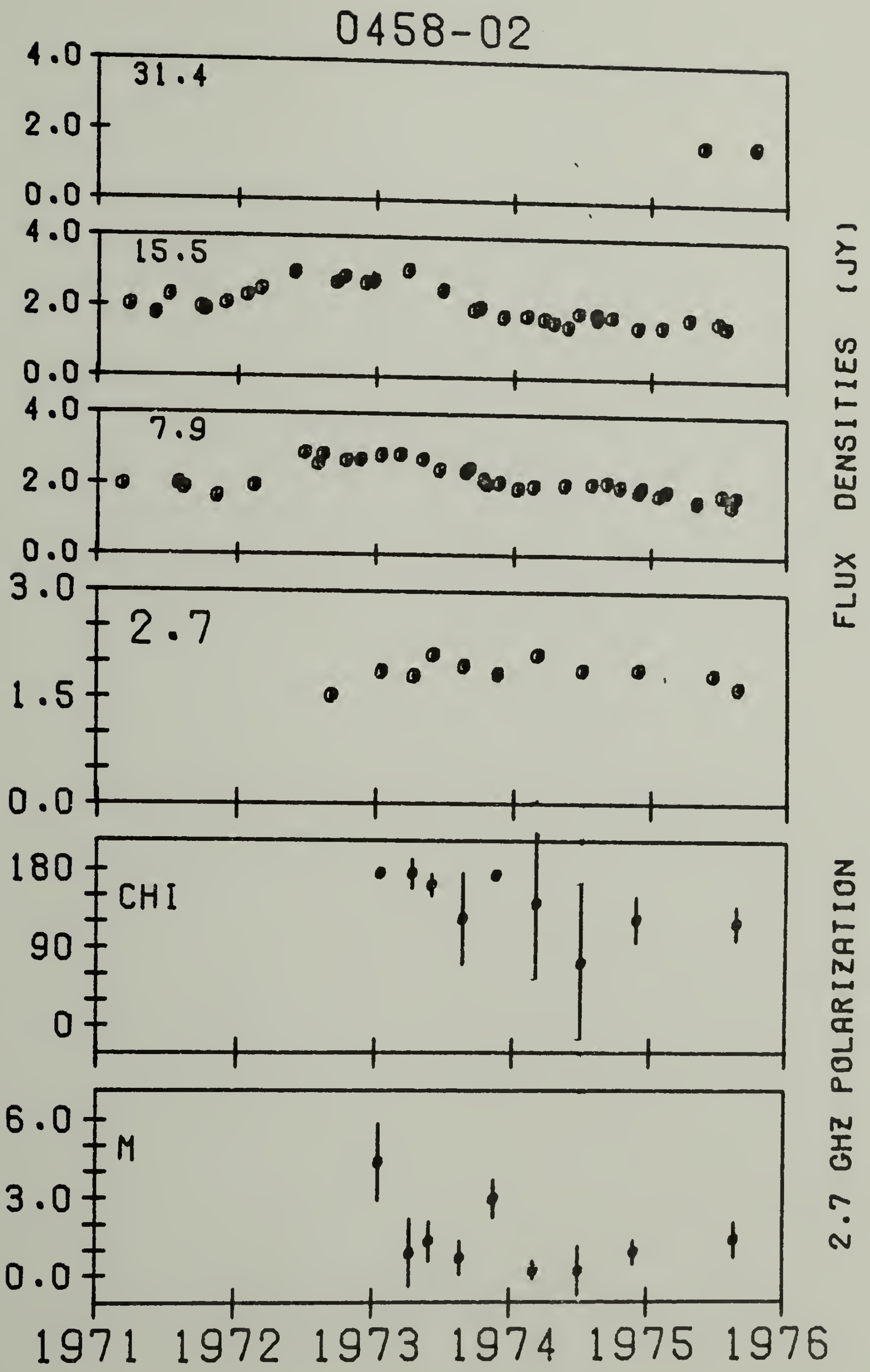
0.0
3.0
4.0
2.5
180
90
0
6.0
3.0
1971 1972 1973 1974 1975 1976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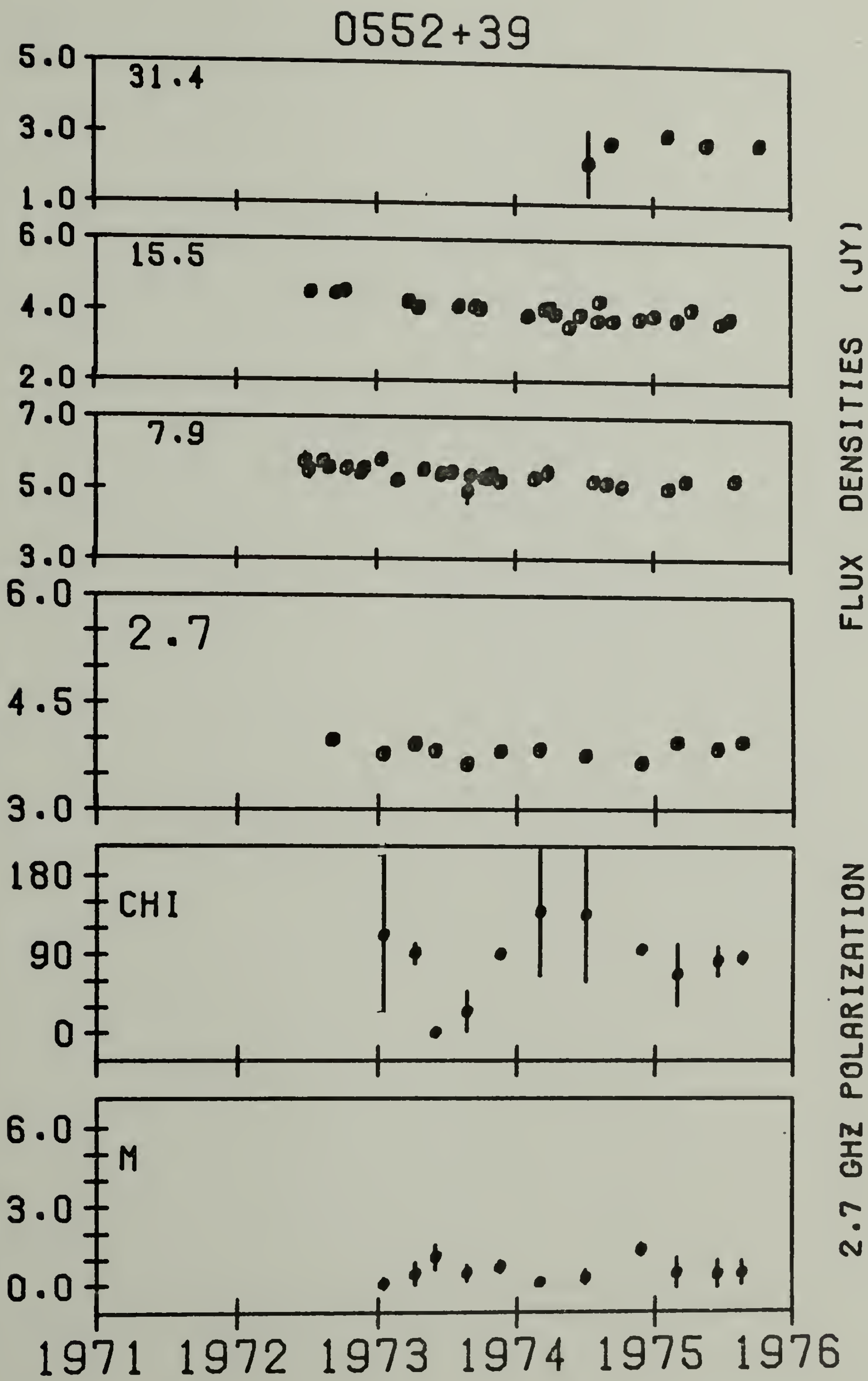
15.5
7.9
2.7
CHI
M
4.0
2.0
0.0
3.0
1.5
180
90
0
6.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION


0552+39
31.4
15.5
7.9
2.7
CHI
M
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
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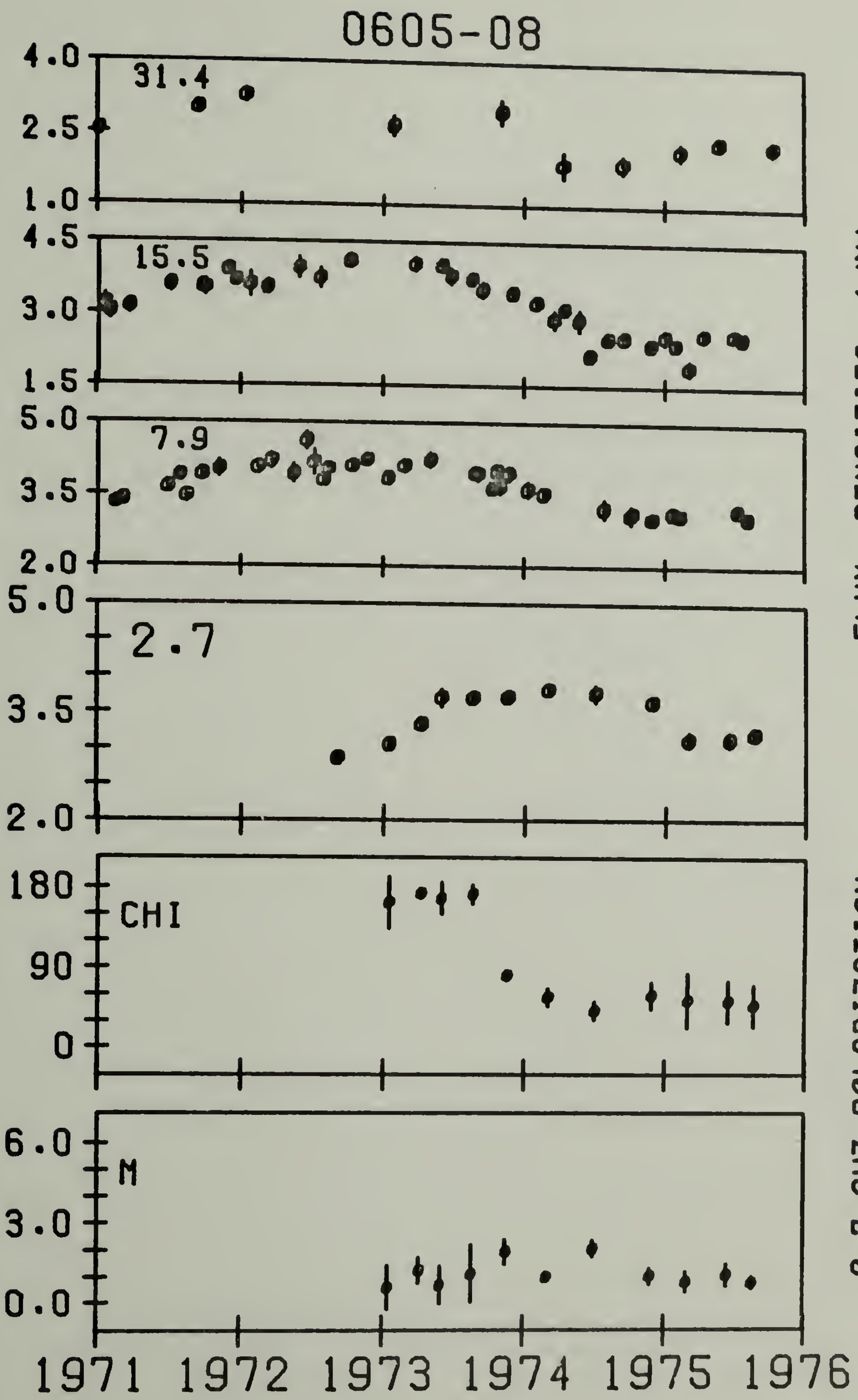
3.0
1.0
6.0
4.0
2.0
7.0
5.0
3.0
6.0
4.5
3.0
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976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15.5
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2.7
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2.5
1.0
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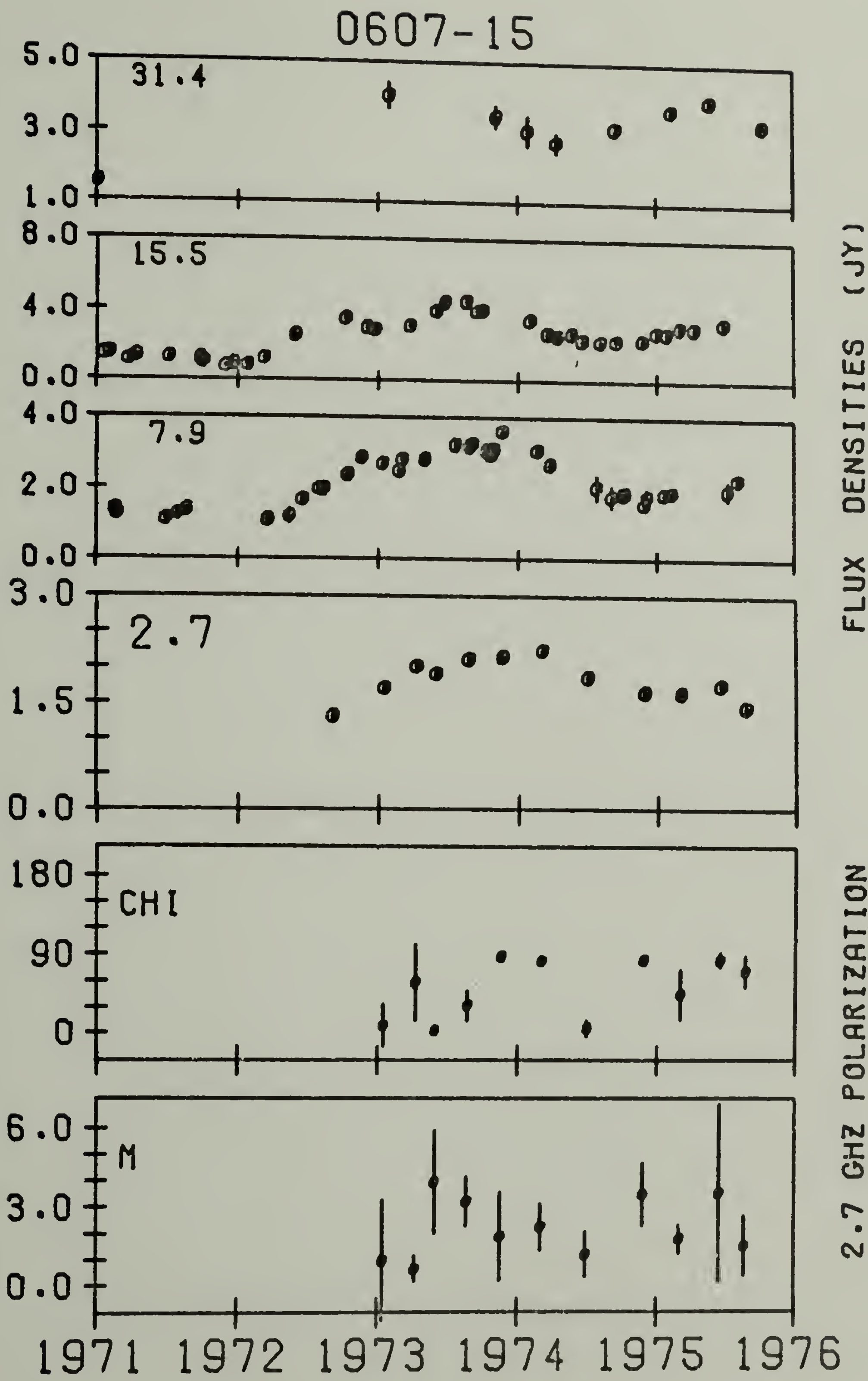
1.5
5.0
3.5
2.0
5.0
3.5
2.0
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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15.5
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2.7
CHI
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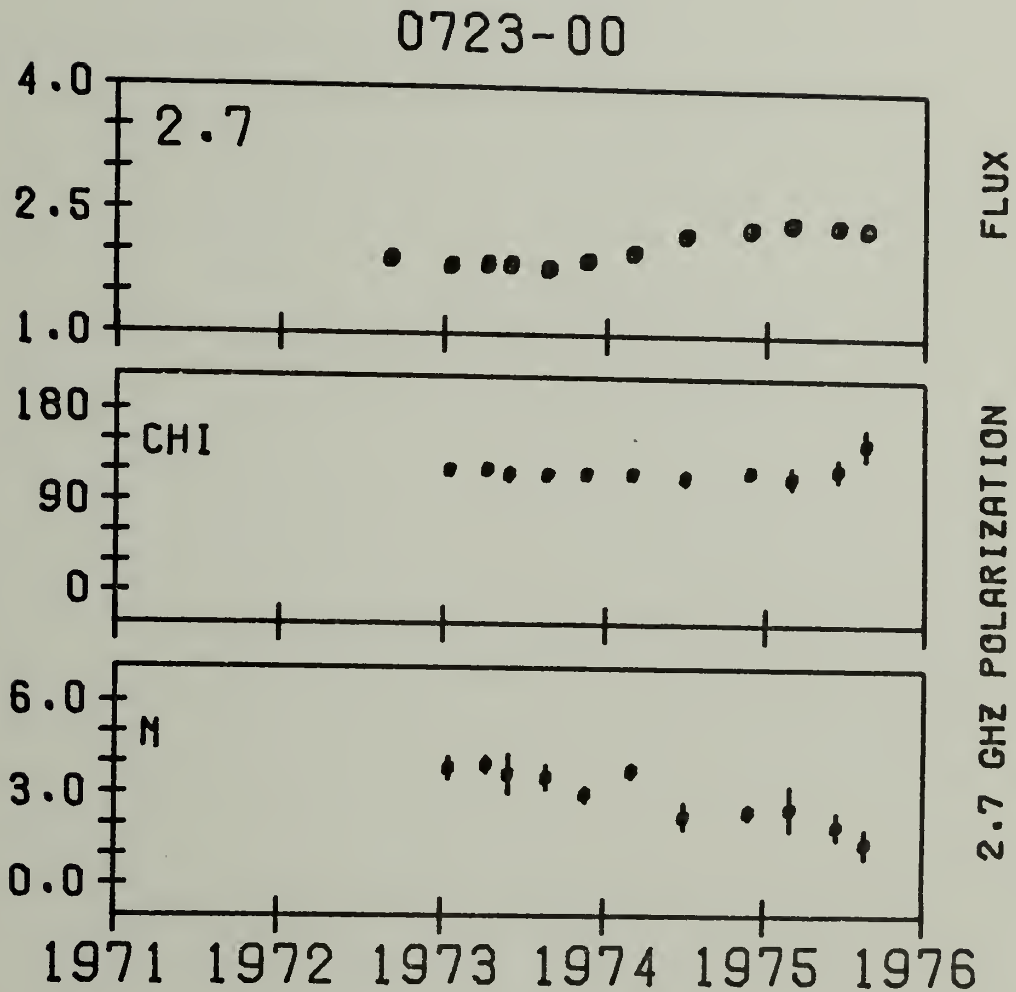
0.0
4.0
2.0
0.0
3.0
1.5
0.0
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION



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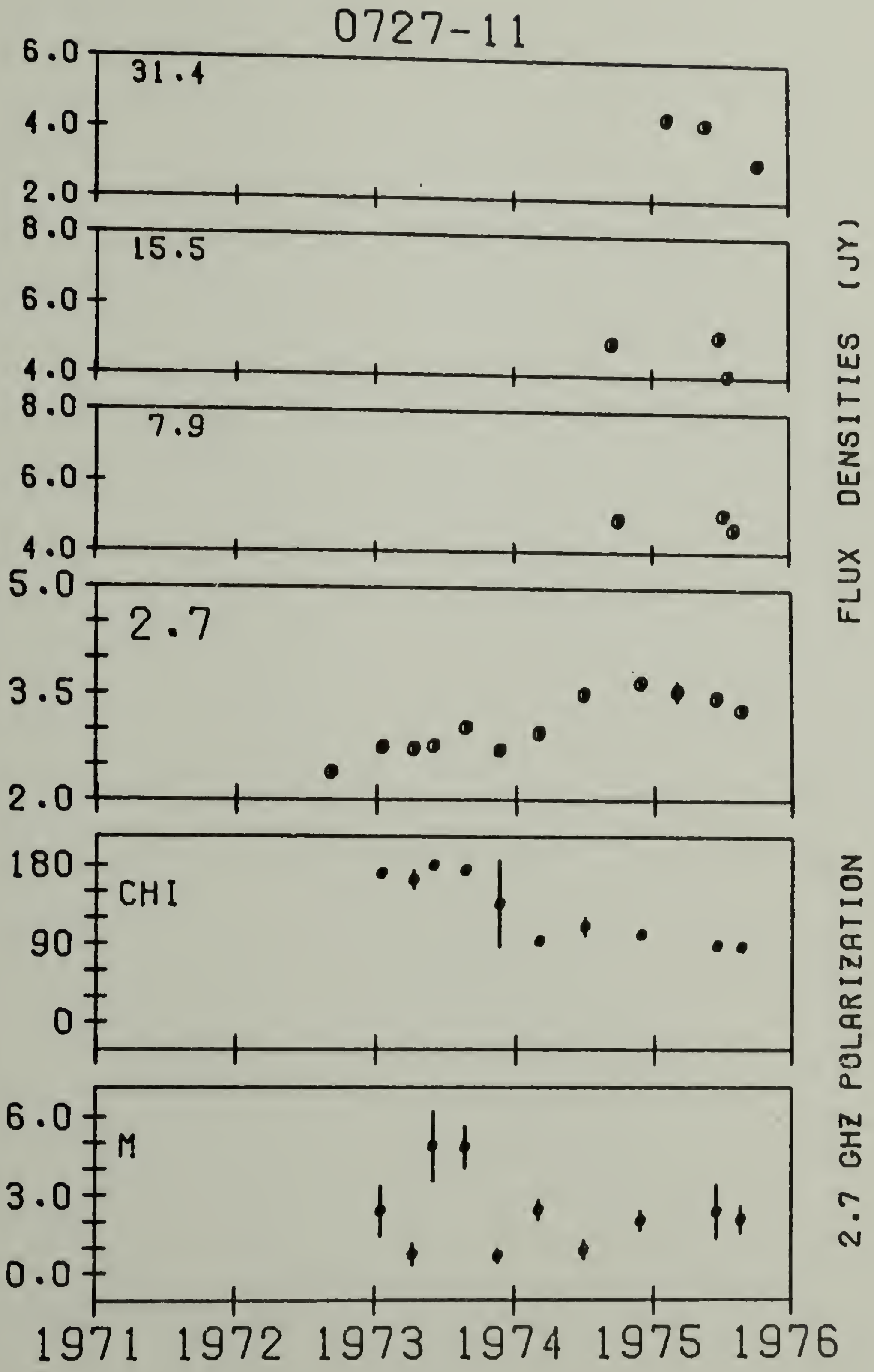
4.0
2.5
1.0
FLUX
CHI
180
90
0
M
6.0
3.0
0.0
2.7 GHZ POLARIZATION
1971
1972
1973
1974
1975
1976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7.9
2.7
CHI
M
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4.0
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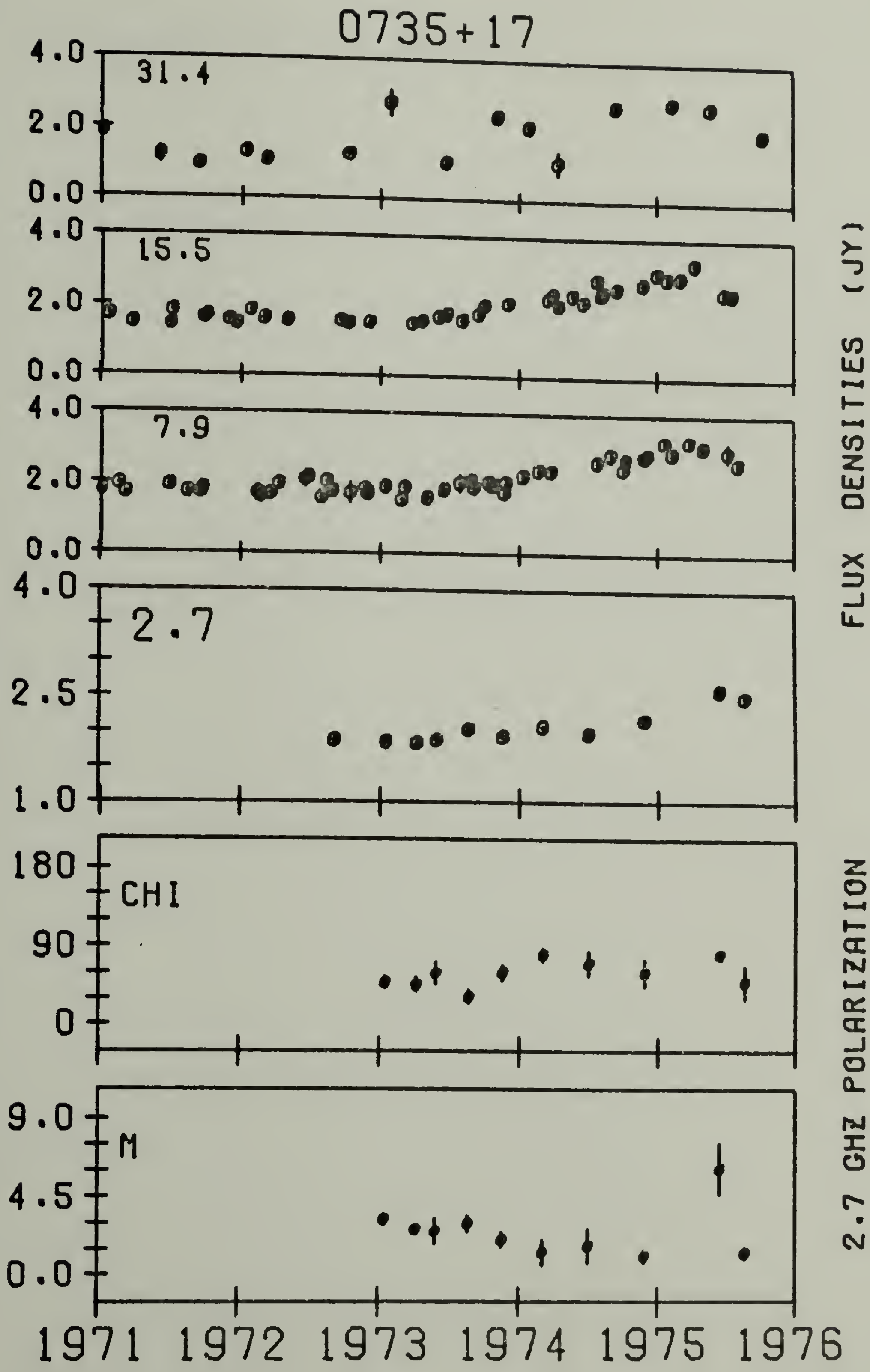
6.0
4.0
8.0
6.0
4.0
5.0
3.5
2.0
180
90
0
6.0
3.0
0.0
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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2.7
CHI
M
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
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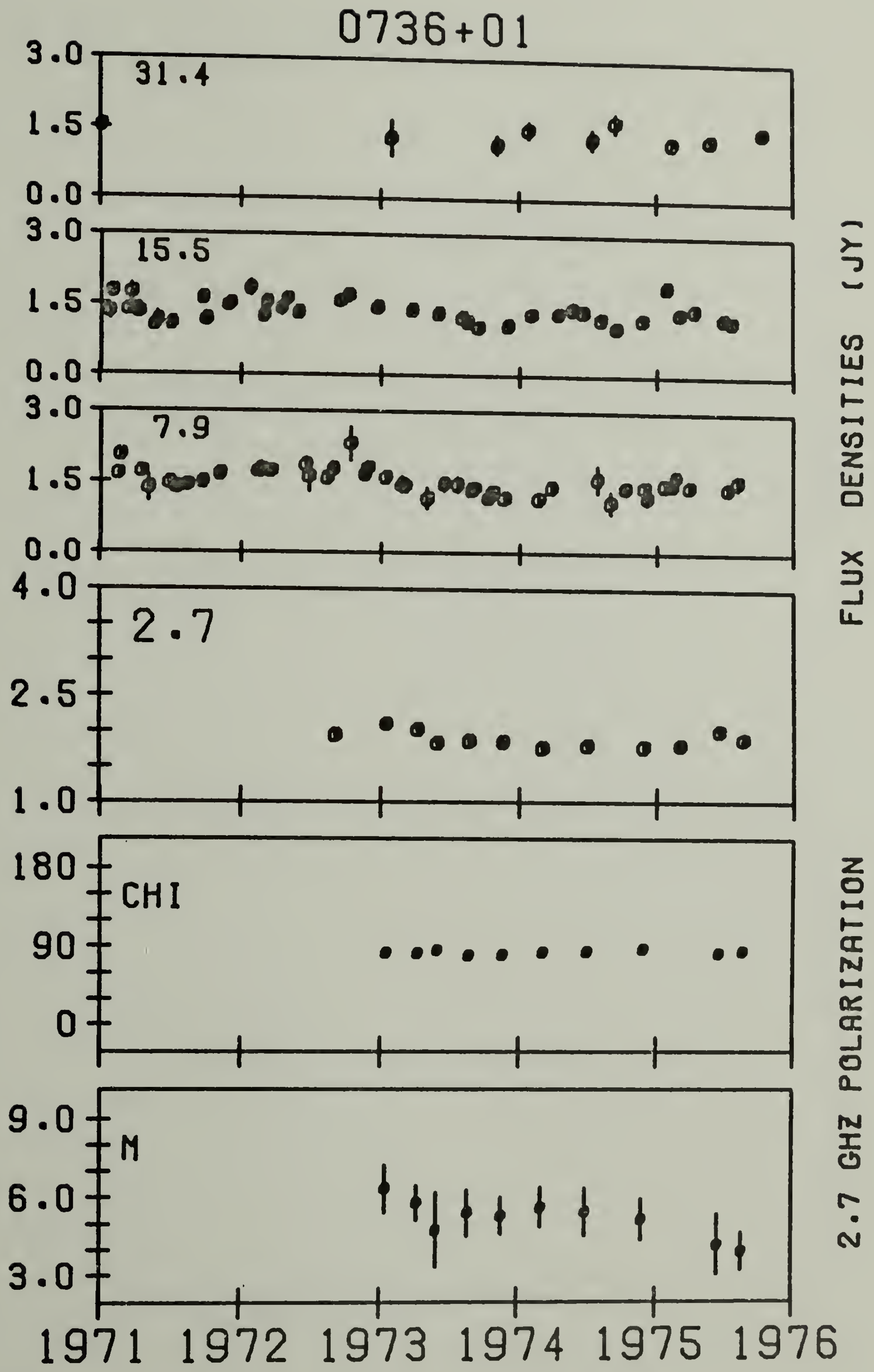
2.0
0.0
2.5
1.0
180
90
0
9.0
4.5
1971 1972 1973 1974 1975 1976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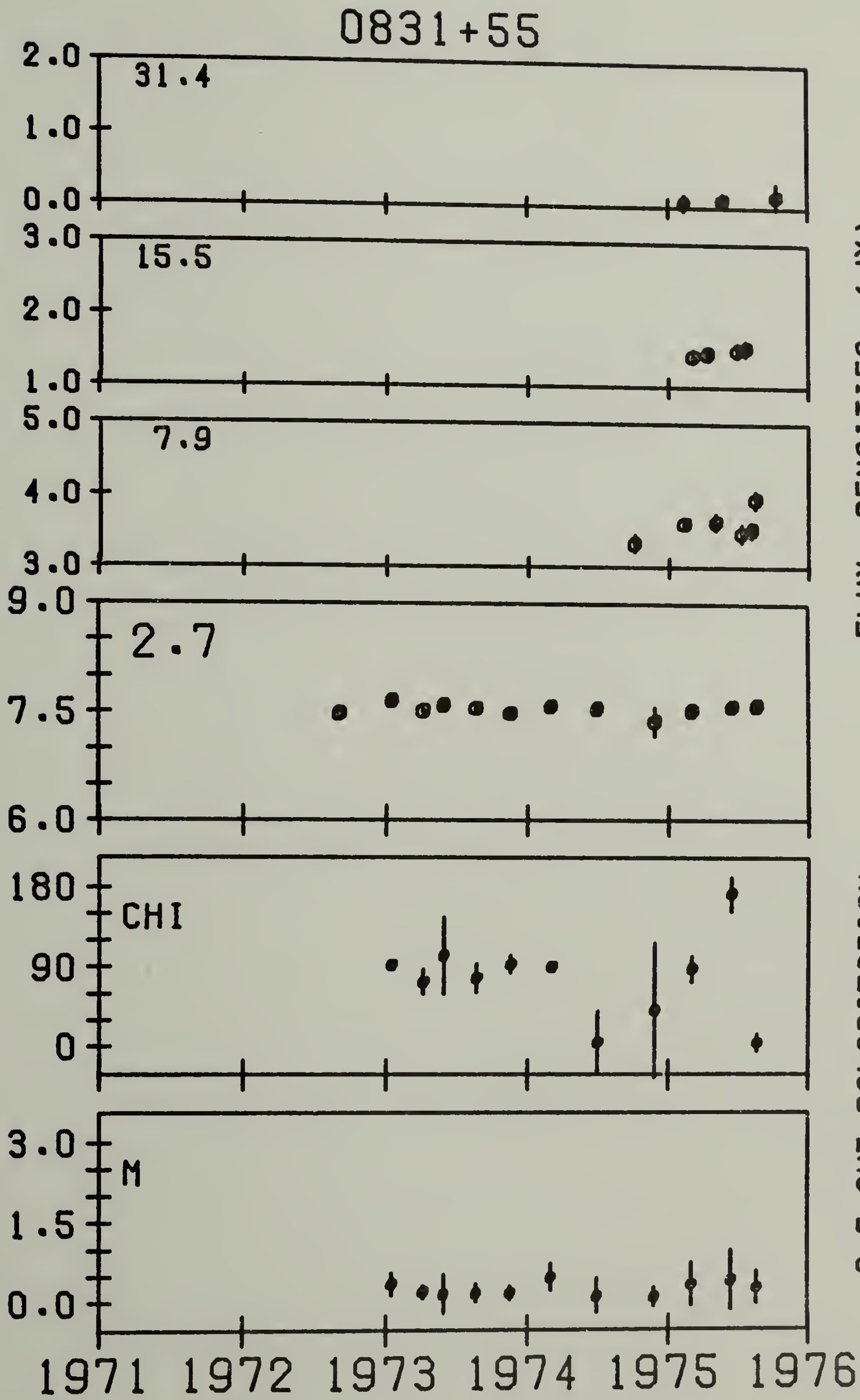
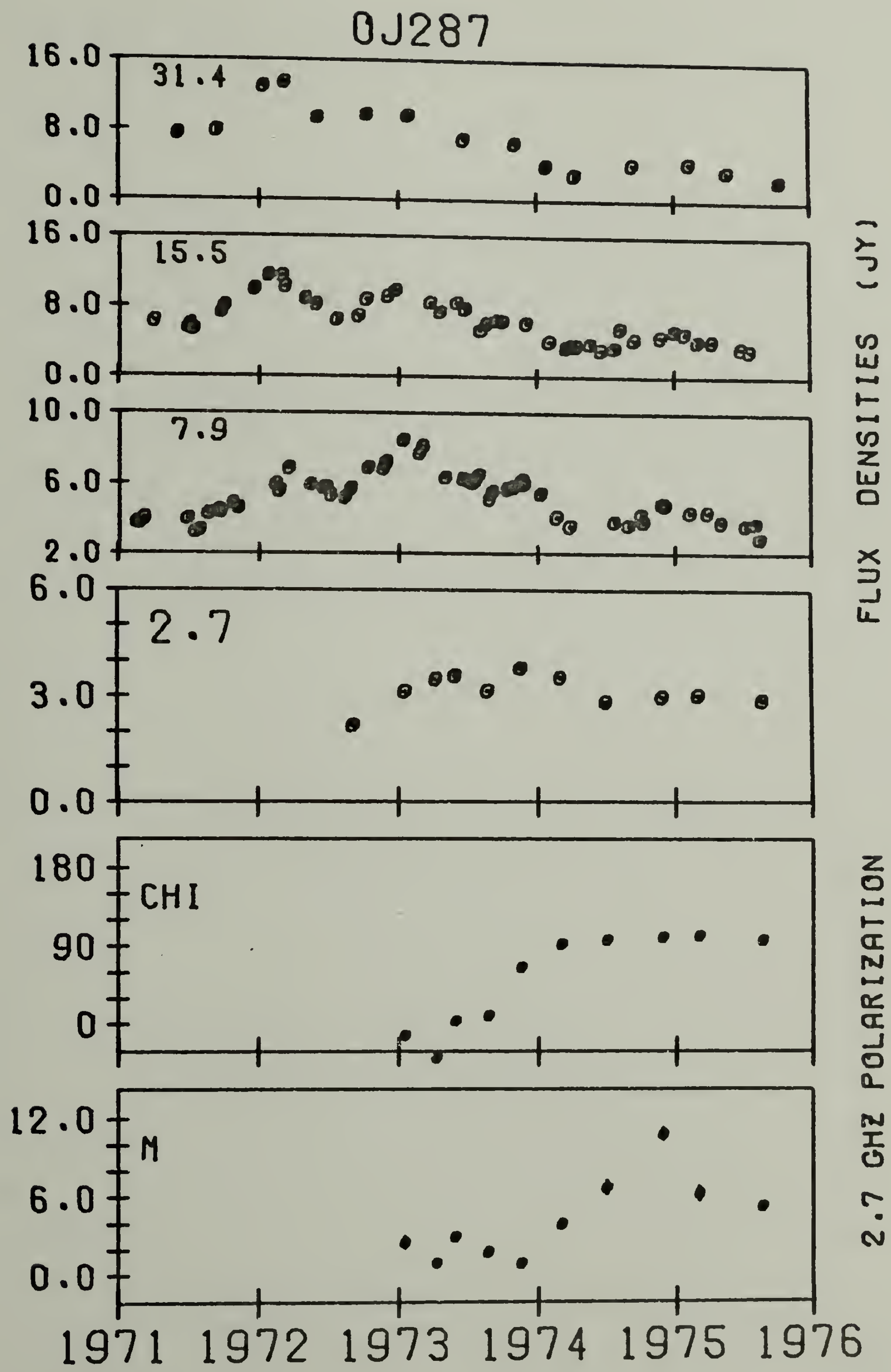
2.7
CHI
M
3.0
1.5
0.0
4.0
2.5
1.0
180
90
0
9.0
6.0
3.0
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
1971
1972
1973
1974
1975
1976



0831+55
31.4
15.5
7.9
2.7
CHI
M
2.0
1.0
0.0
3.0
2.0
1.0
5.0
4.0
3.0
9.0
7.5
6.0
180
90
0
3.0
1.5
0.0
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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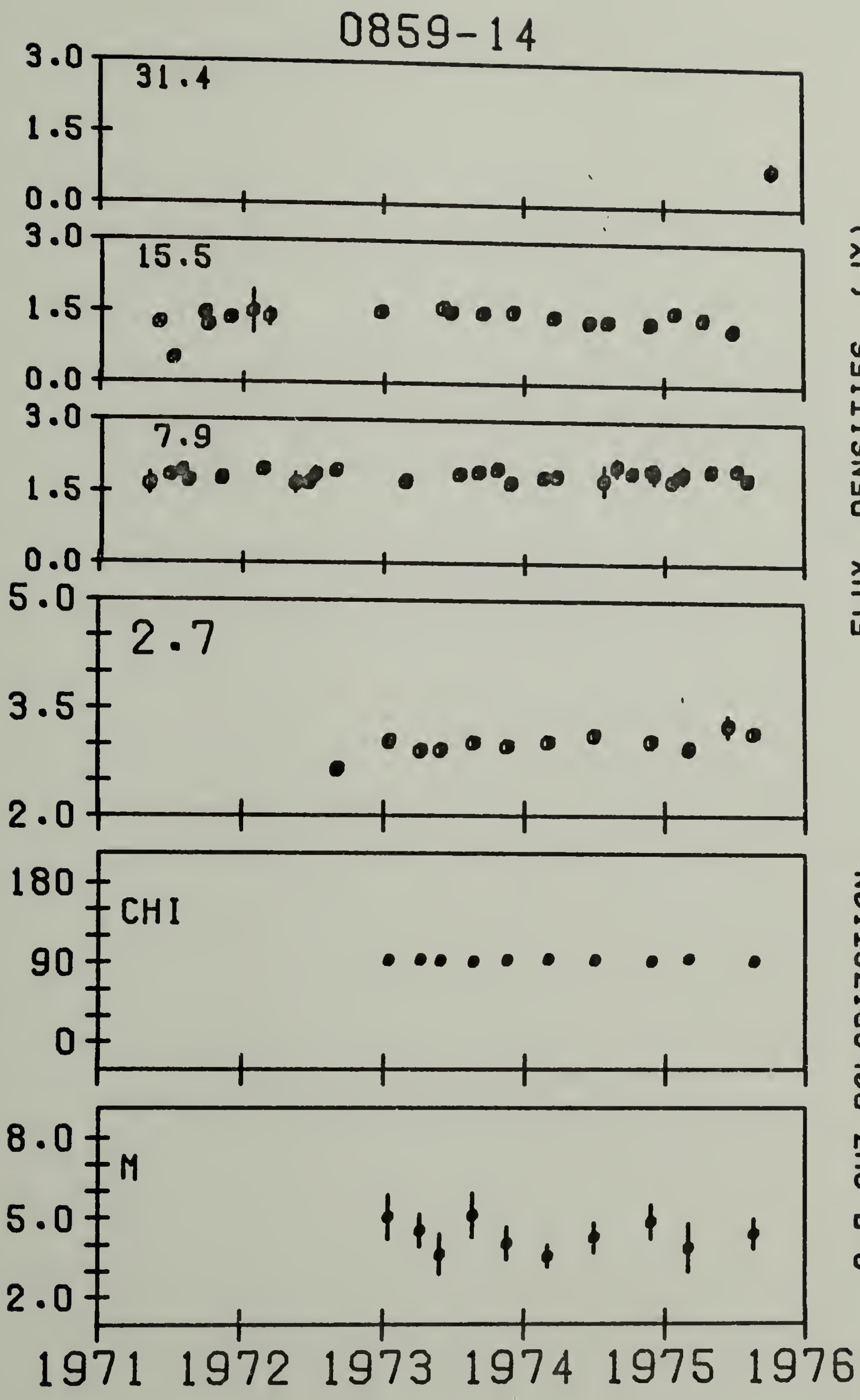
10.0
6.0
2.0
7.9
6.0
3.0
0.0
2.7
180
90
0
CHI
12.0
6.0
0.0
M
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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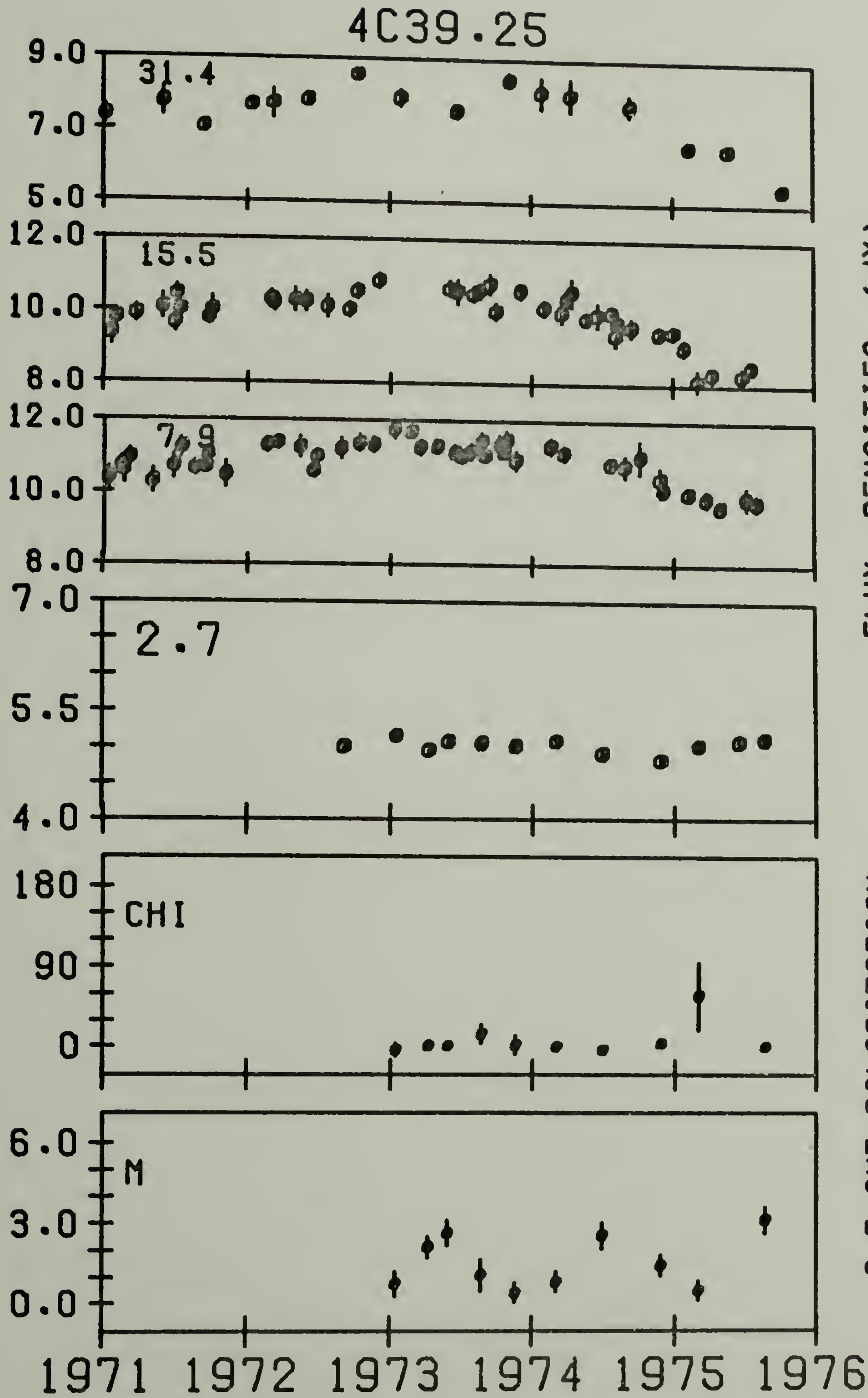
31.4
15.5
7.9
5.0
3.5
2.0
2.7
180
90
0
CHI
8.0
5.0
2.0
M
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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CHI
M
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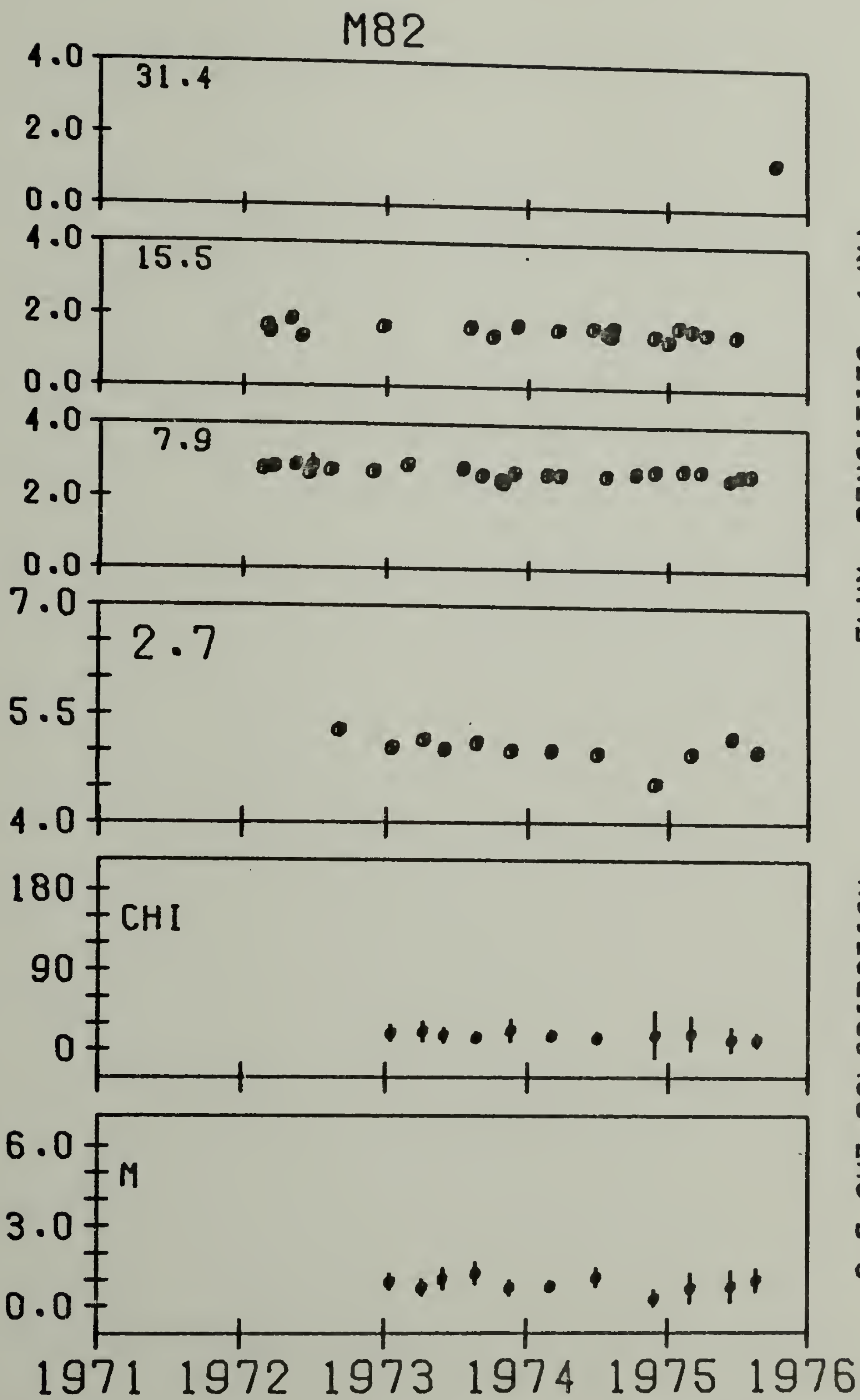
5.0
12.0
10.0
8.0
12.0
10.0
8.0
7.0
5.5
4.0
180
90
0
6.0
3.0
0.0
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
1971
1972
1973
1974
1975
1976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FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
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1975
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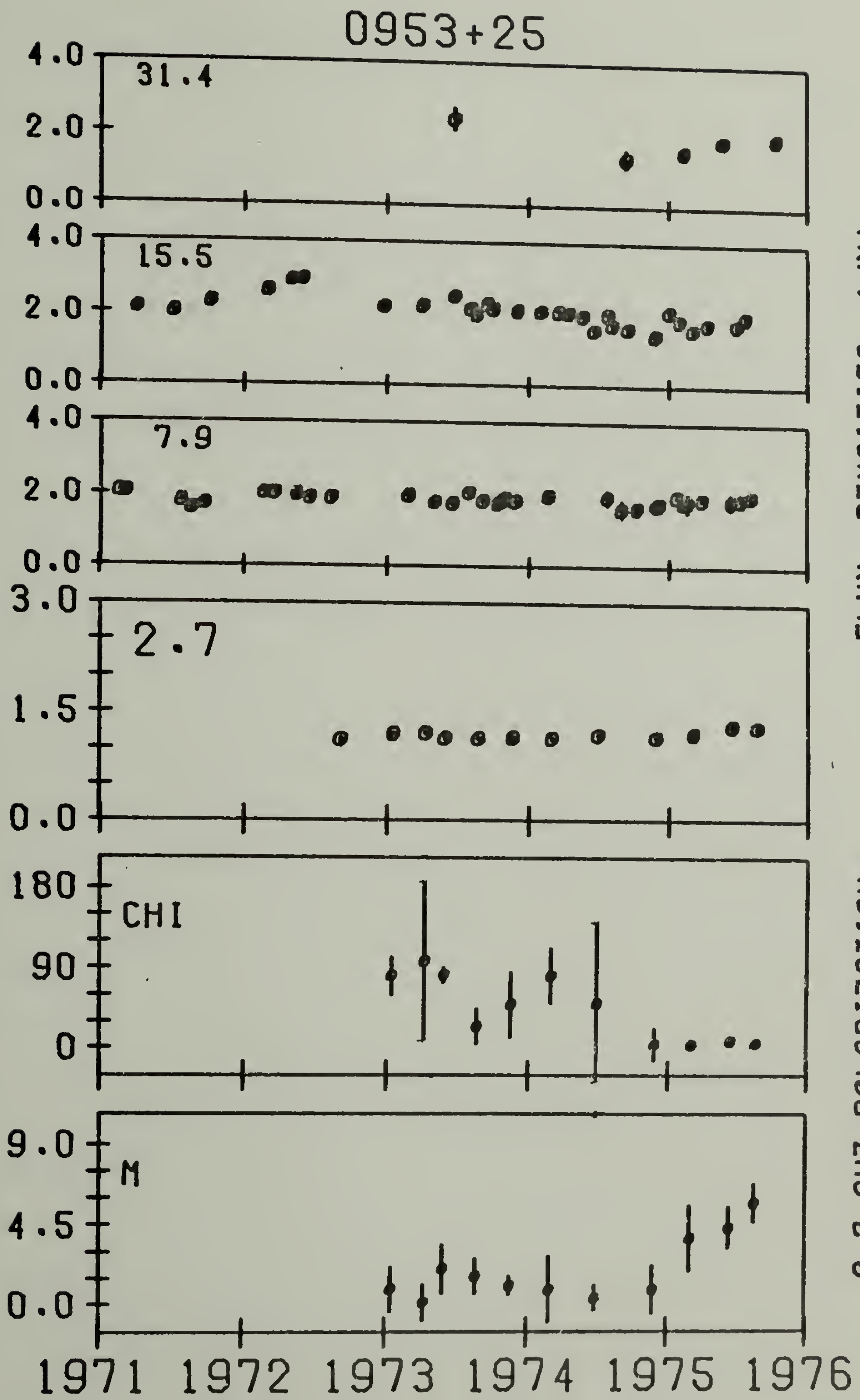
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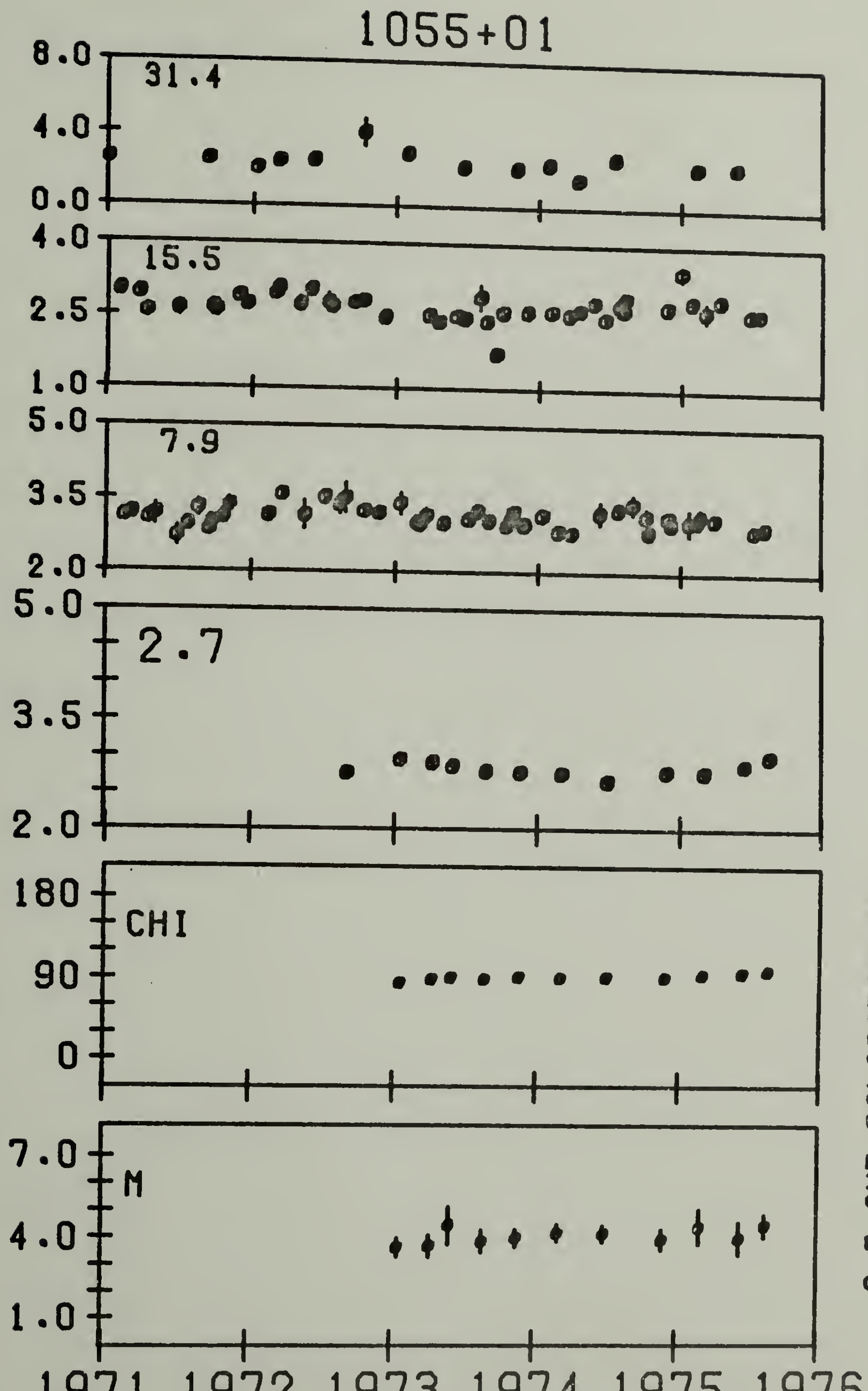
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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1975
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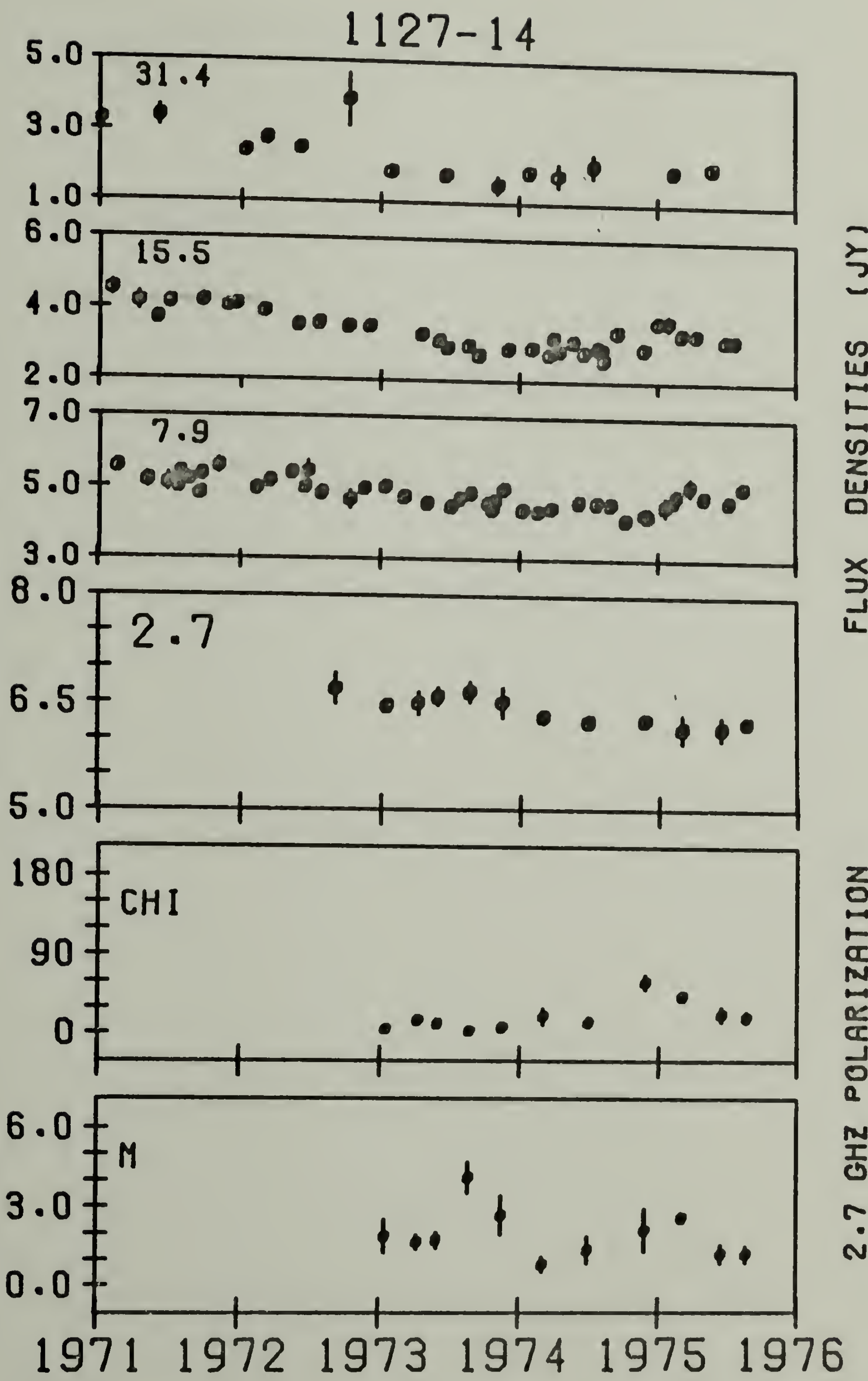
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1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
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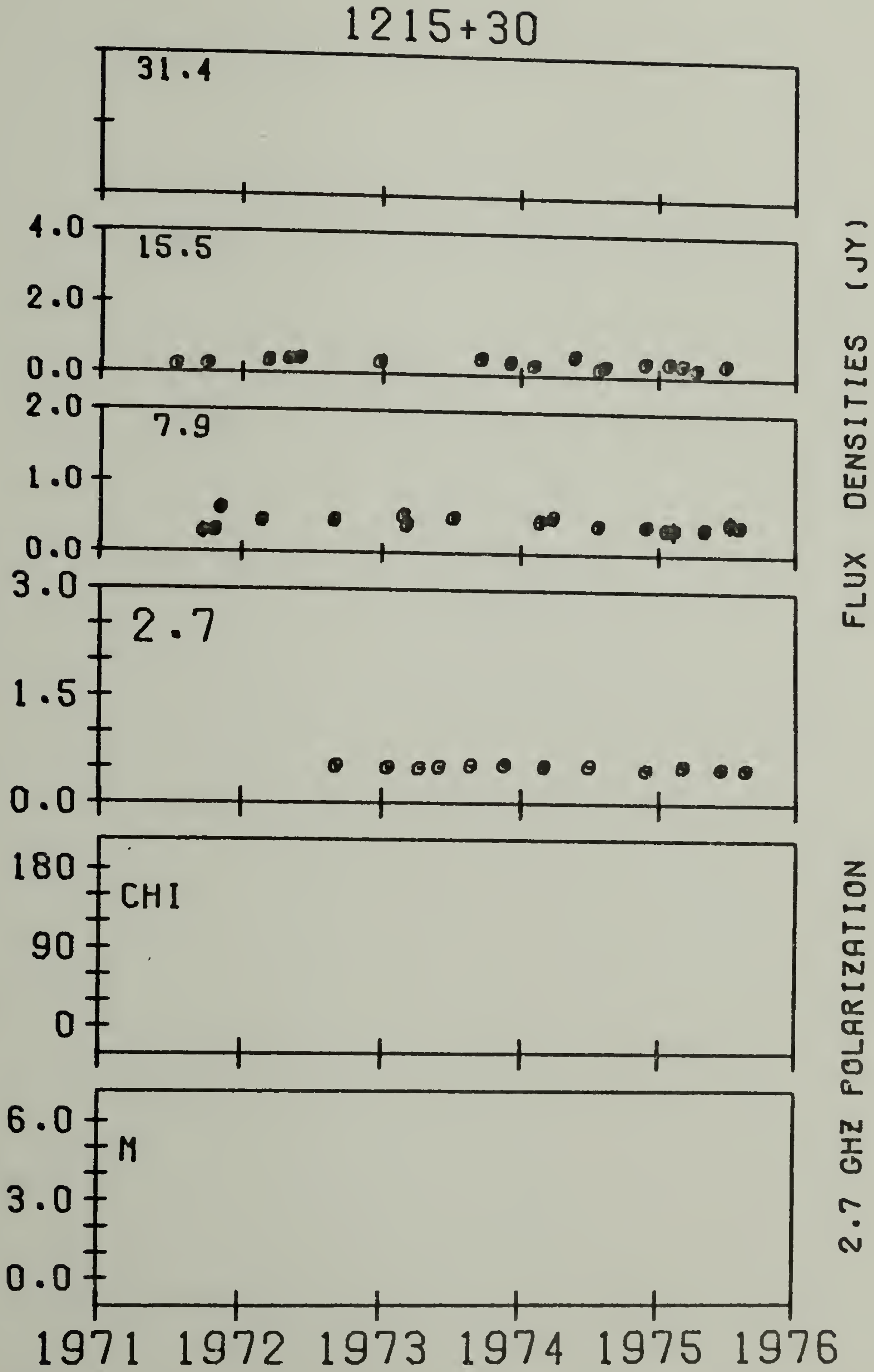
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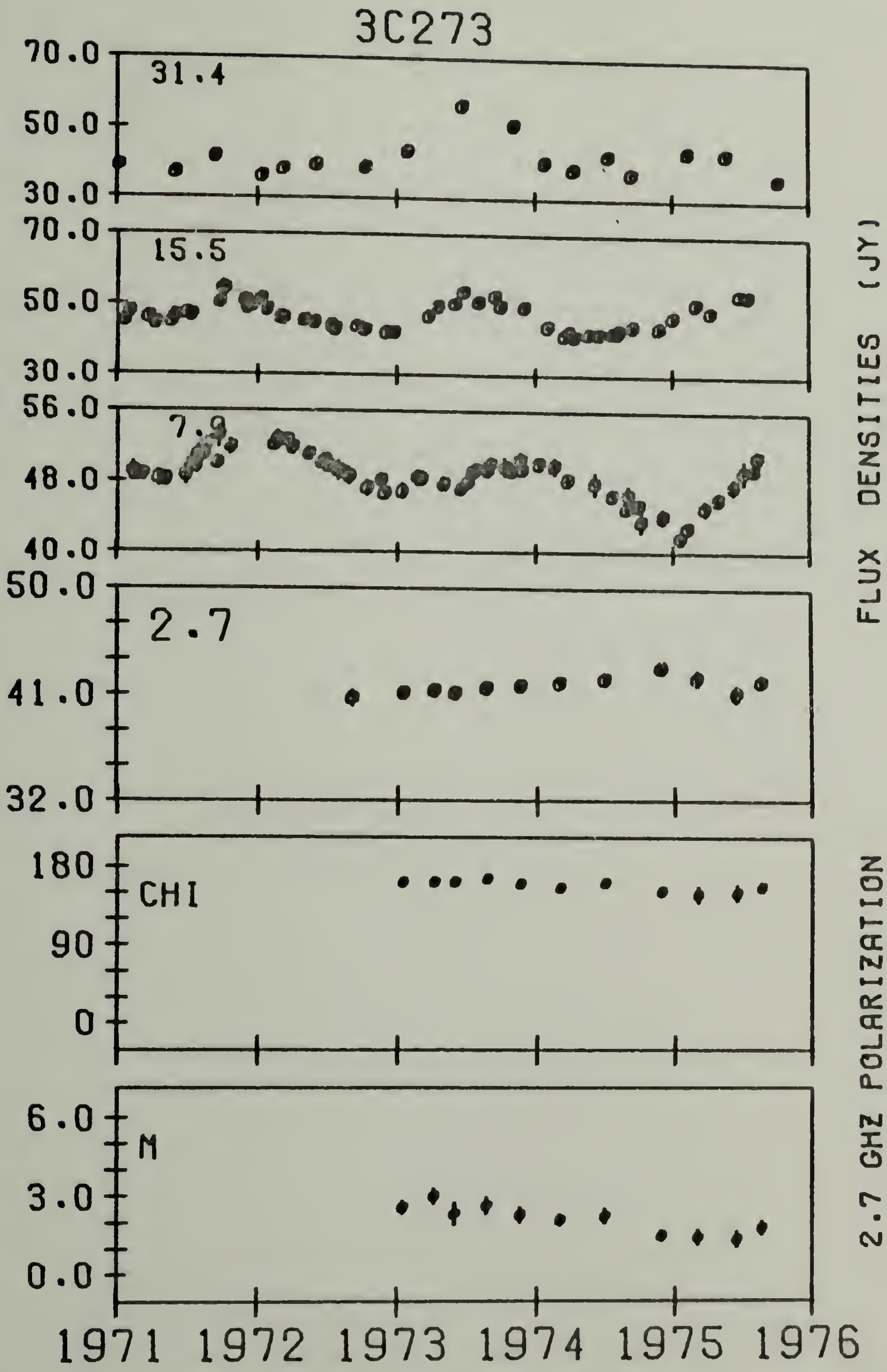
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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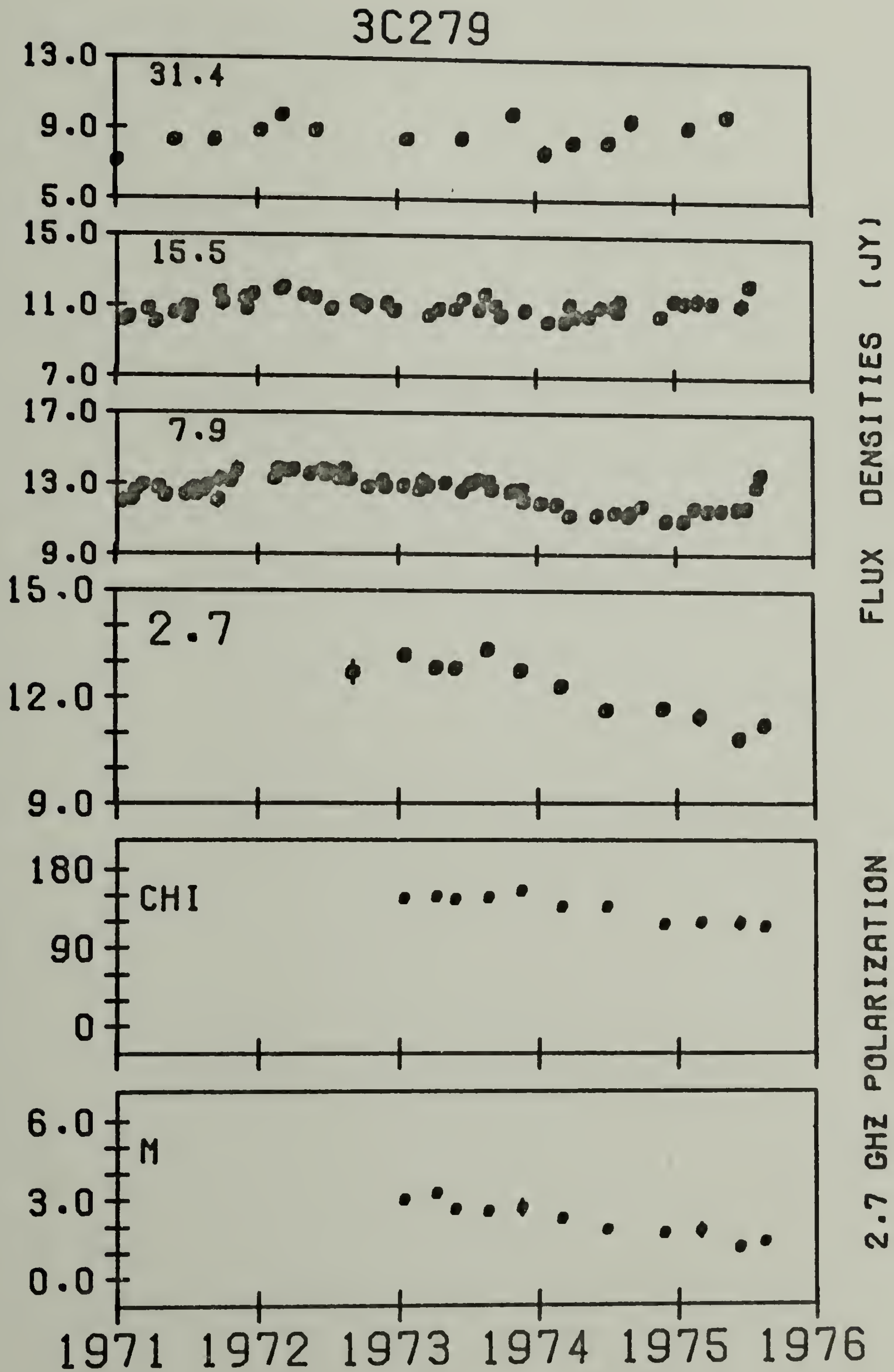
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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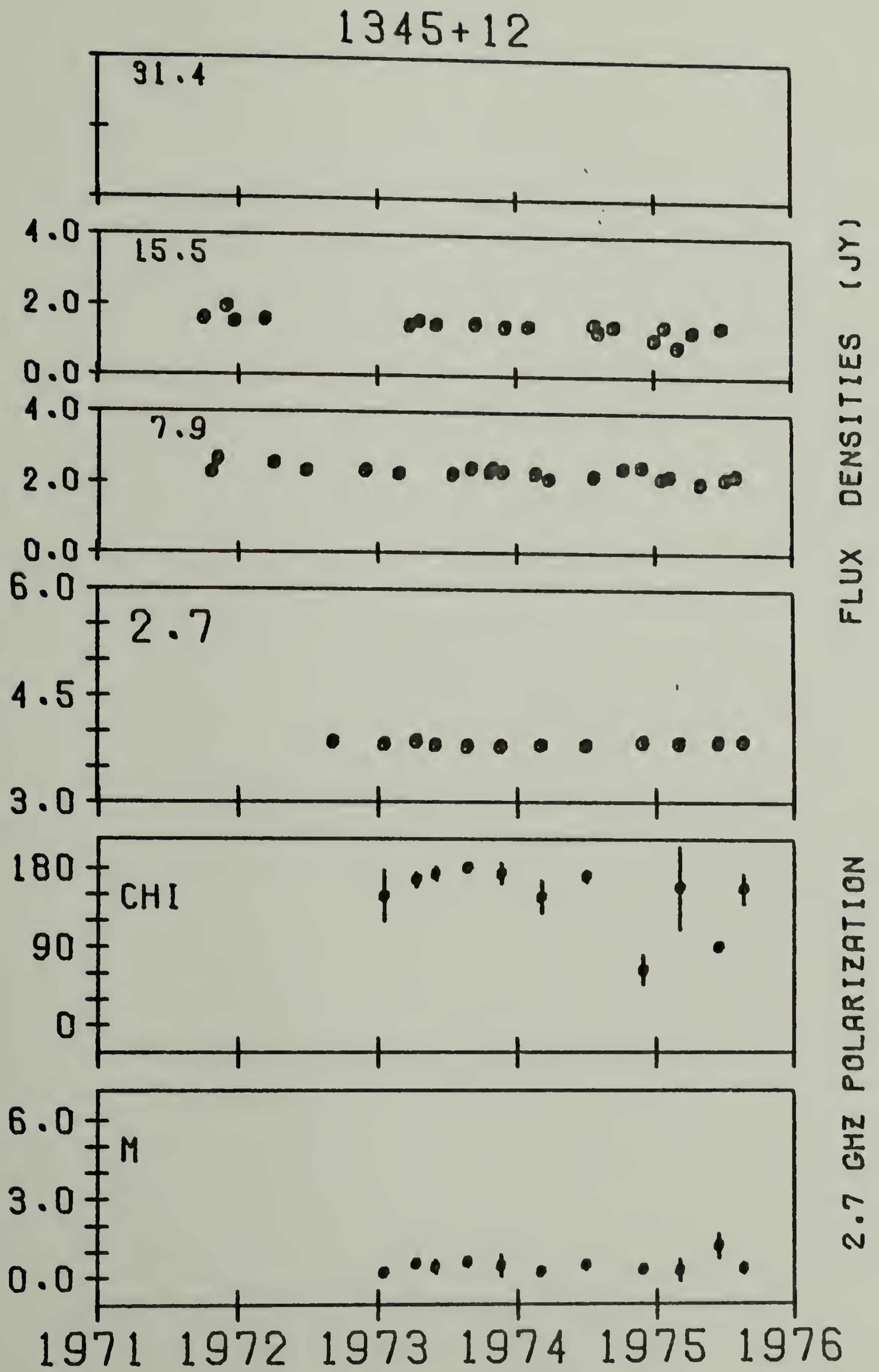
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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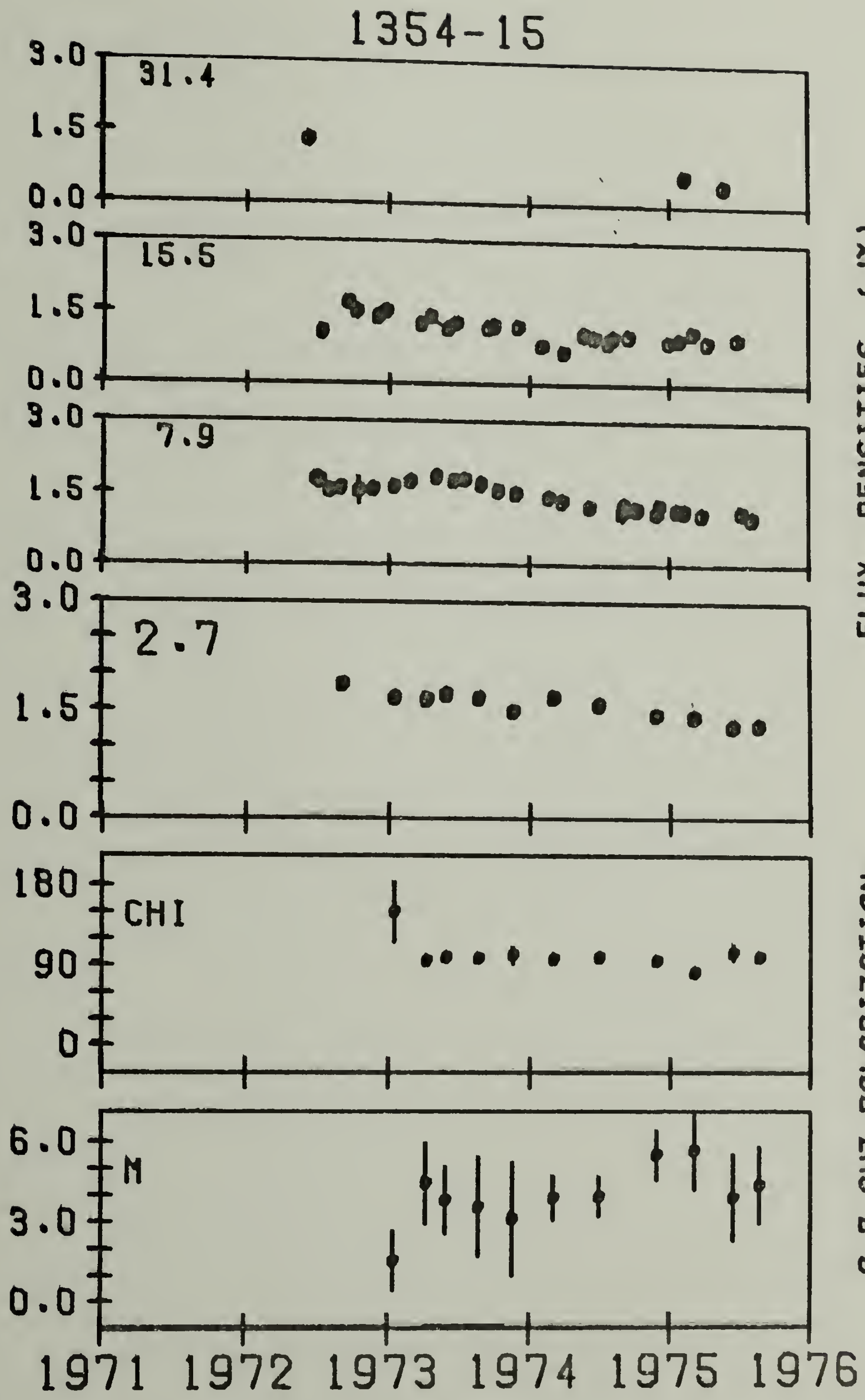
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FLUX DENSITIES (JY)
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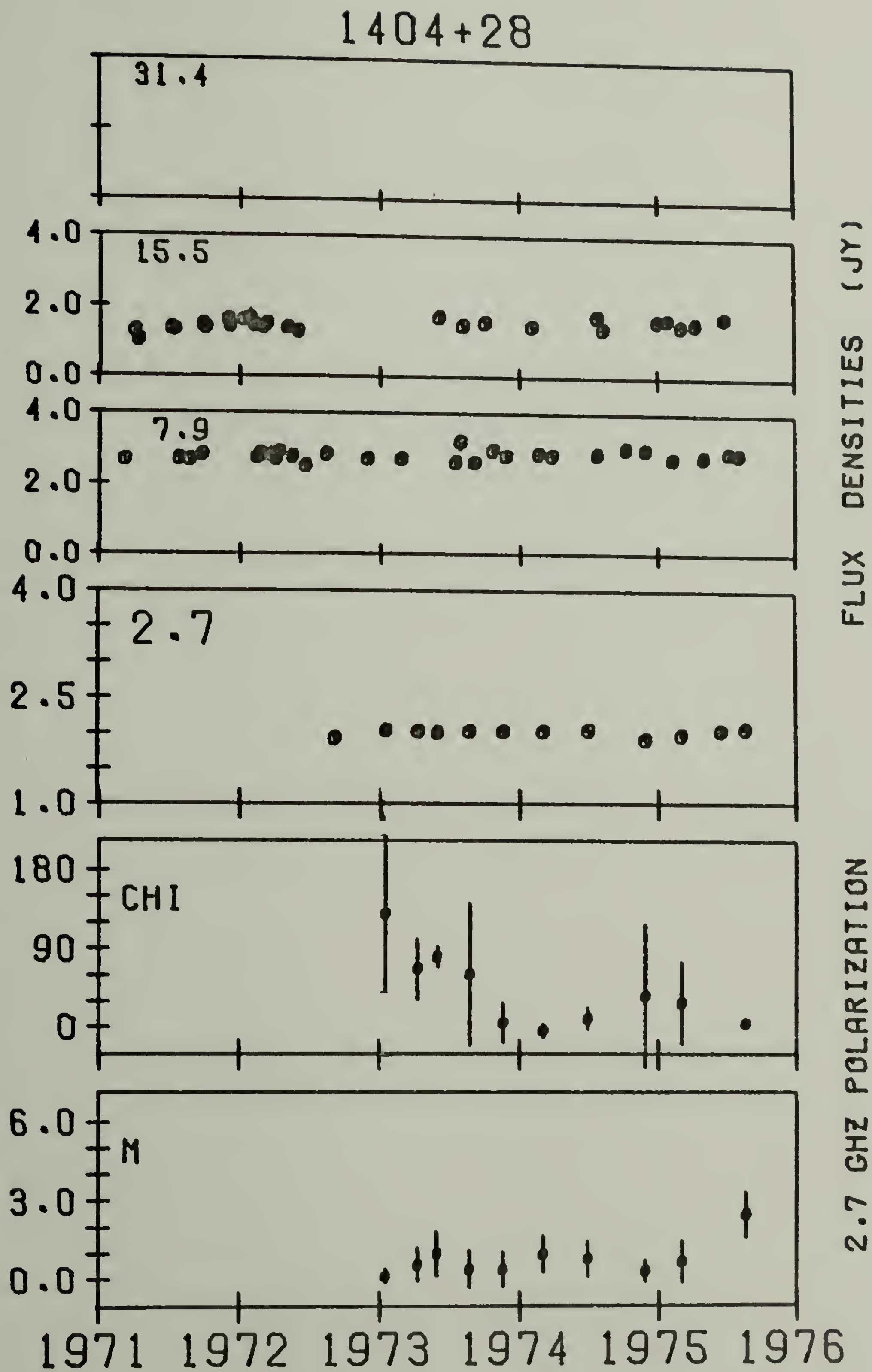
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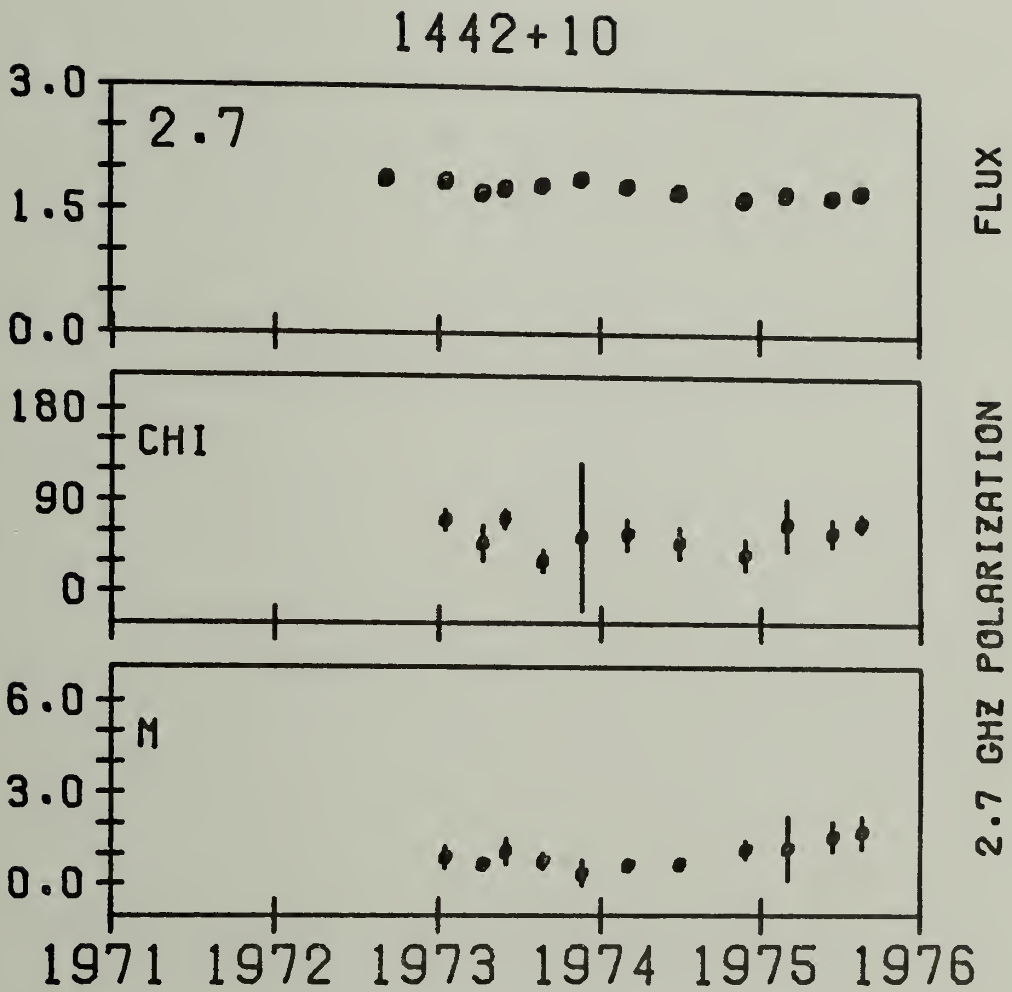
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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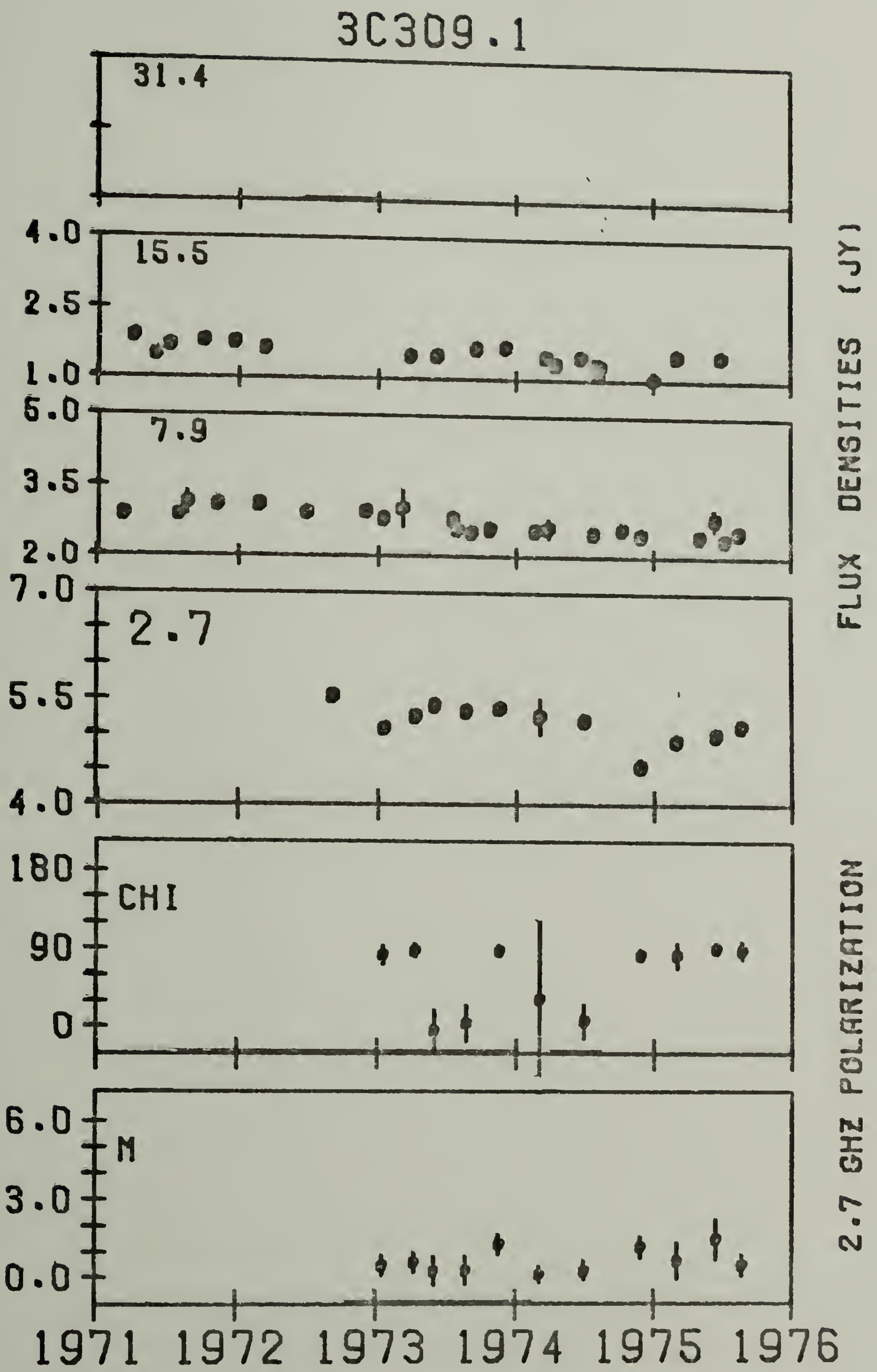
1971 1972 1973 1974 1975 1976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FLUX DENSITIES (JY)
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M
2.7 GHZ POLARIZATION
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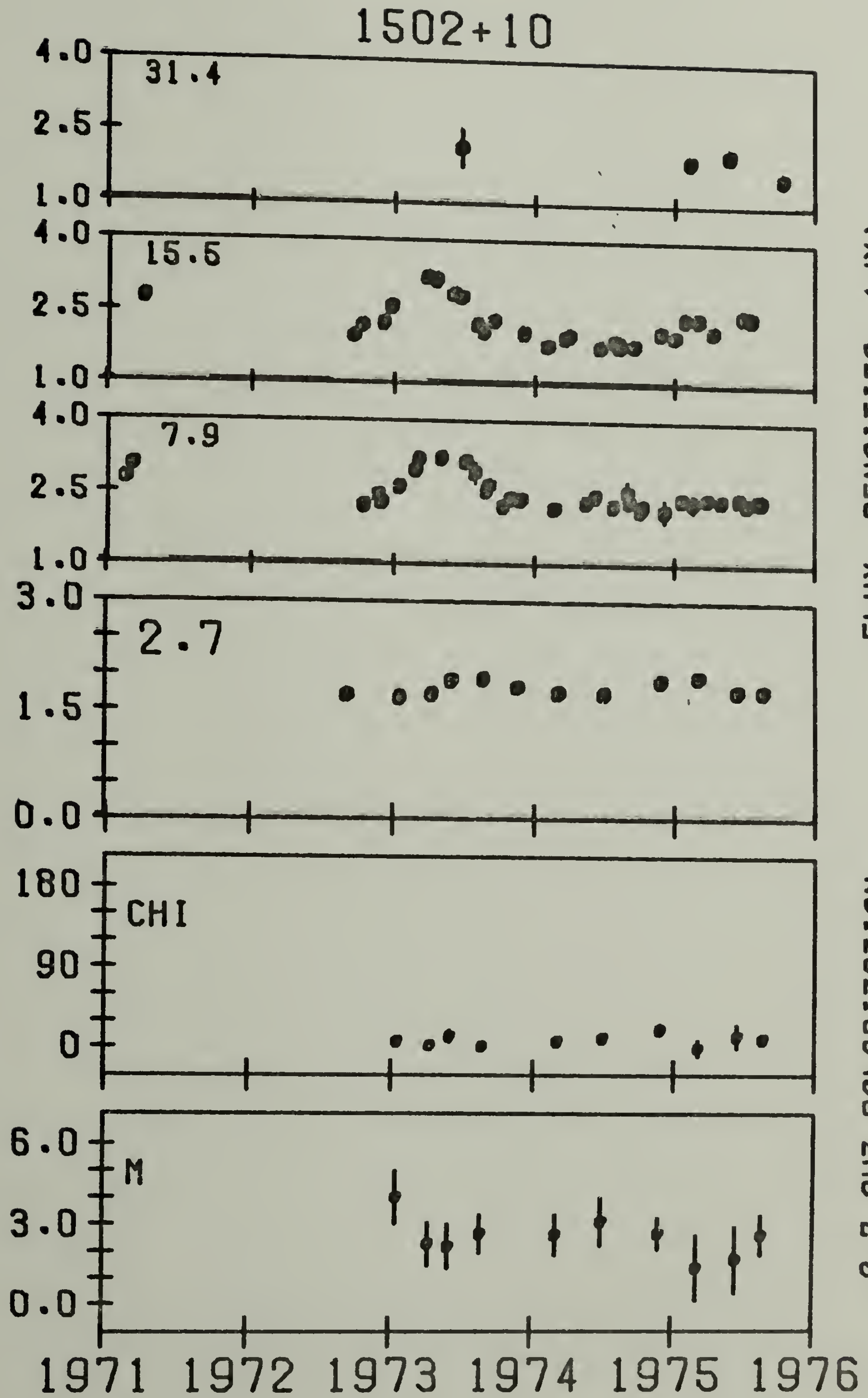
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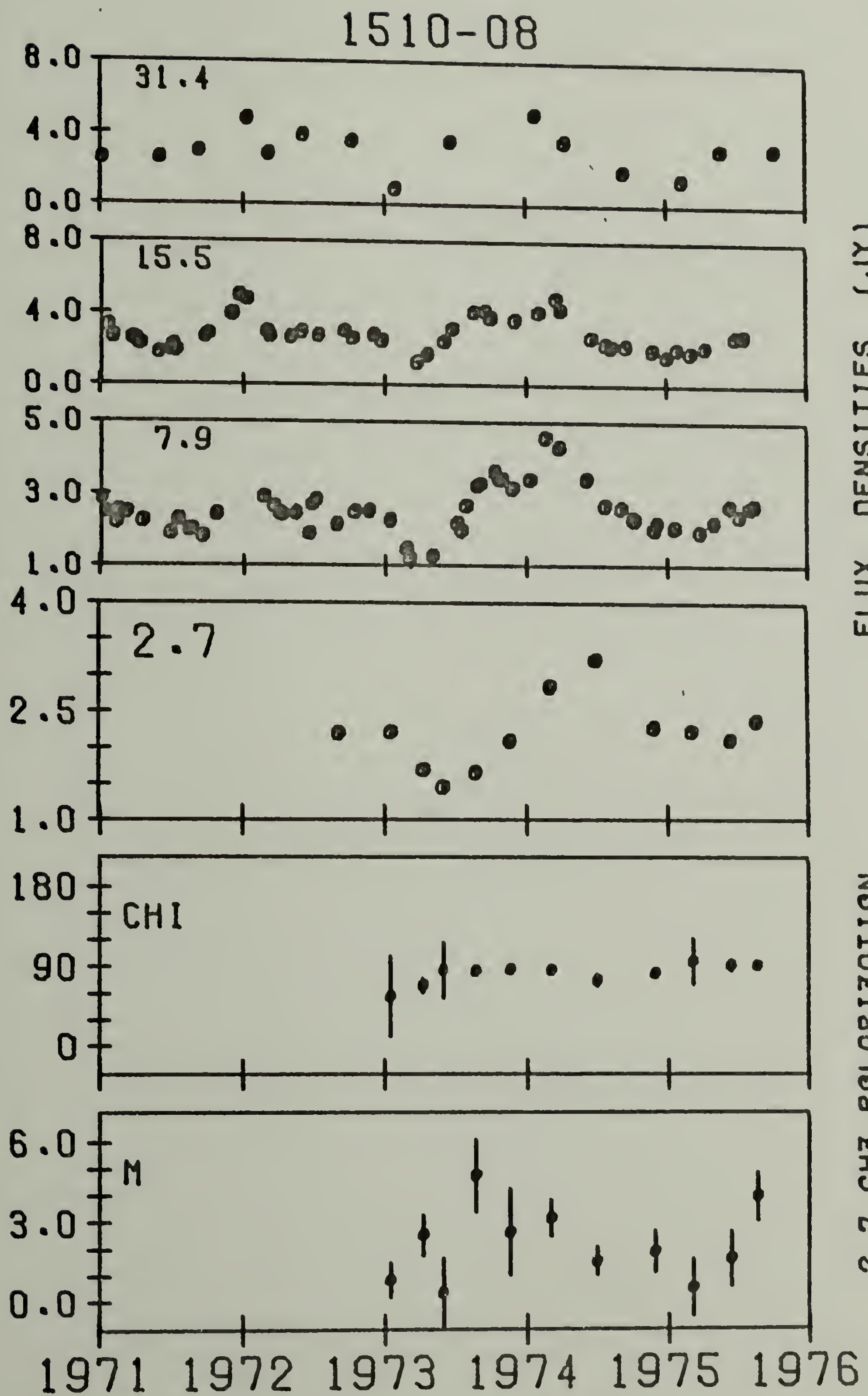
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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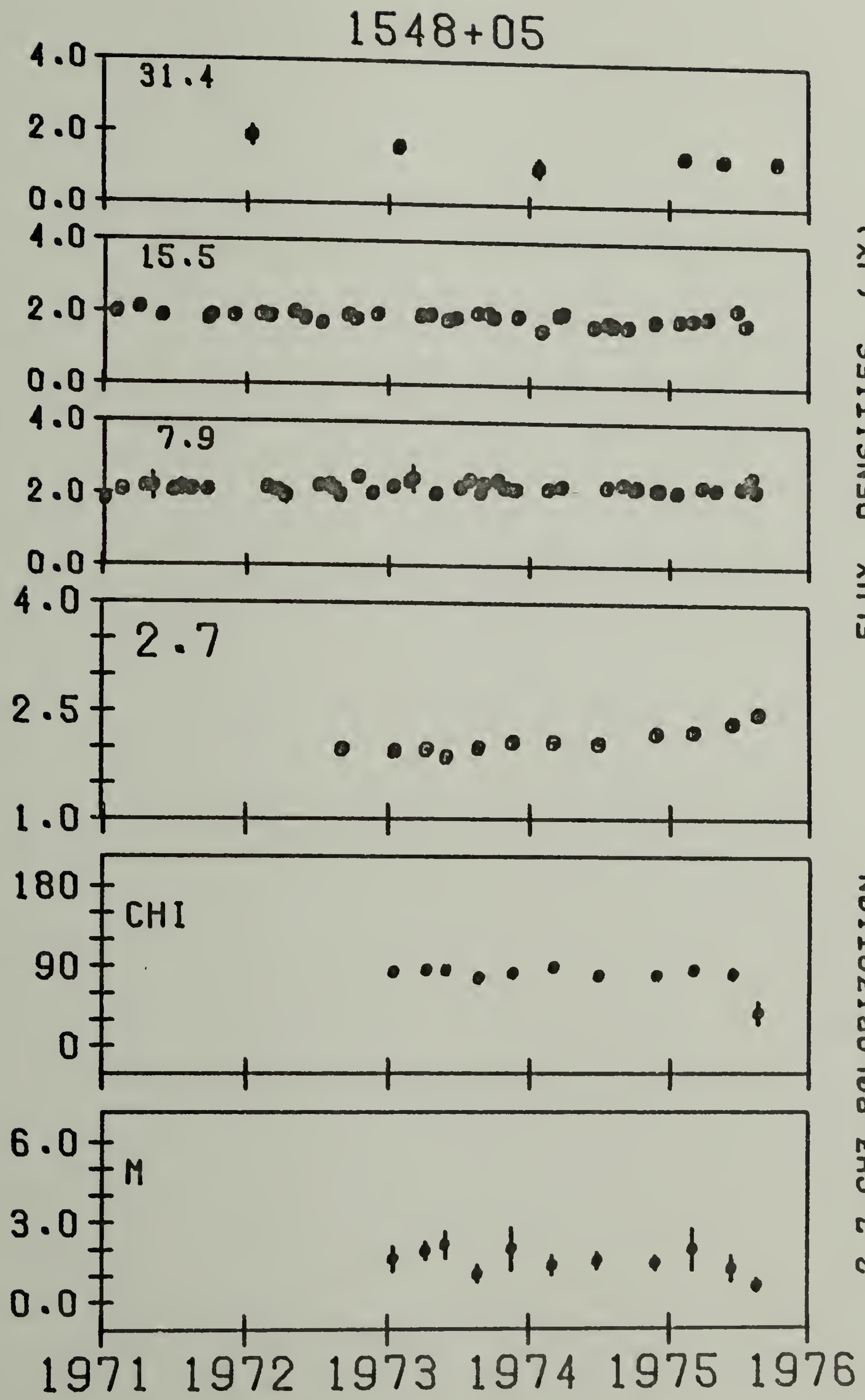
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FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
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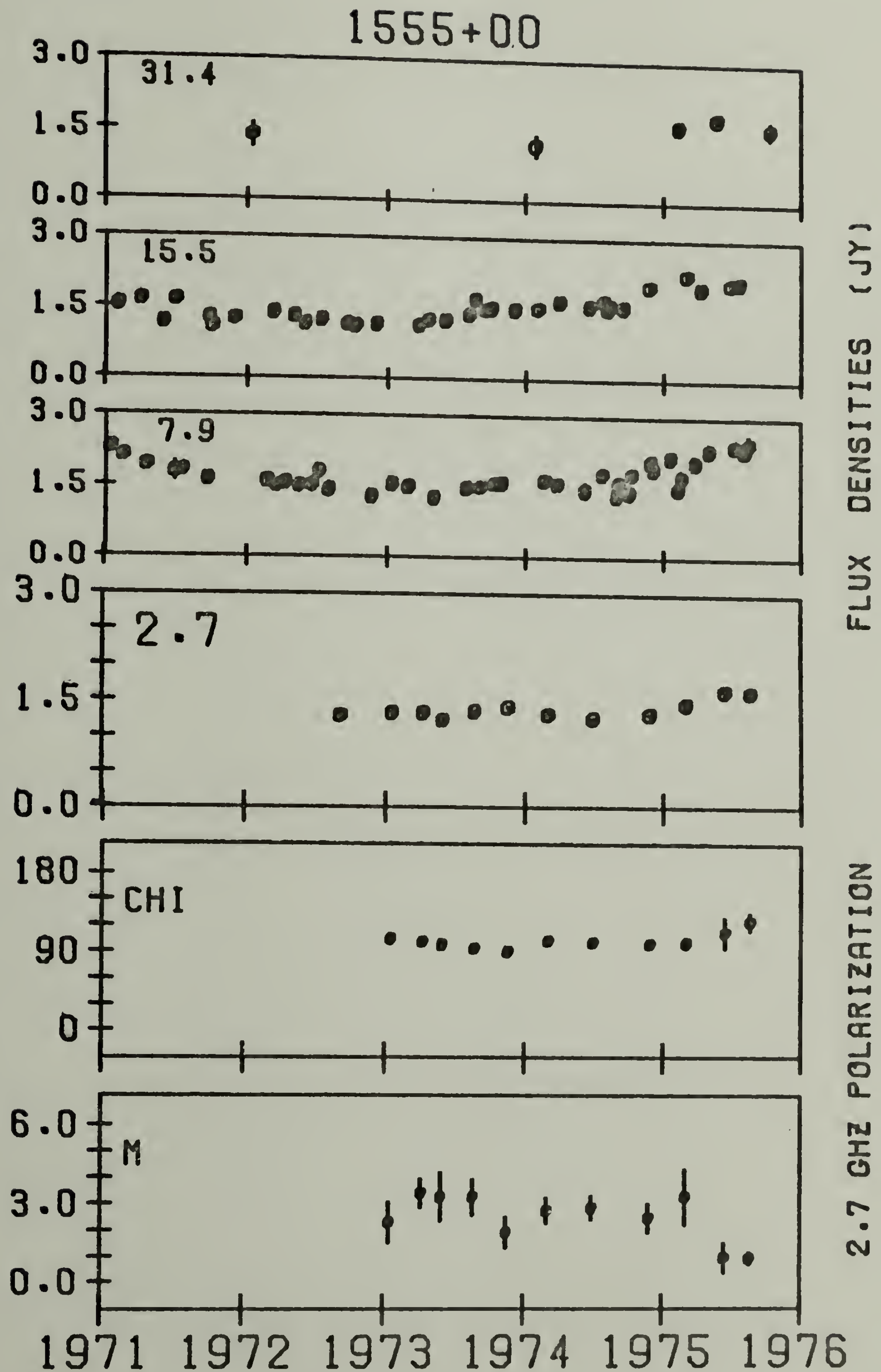
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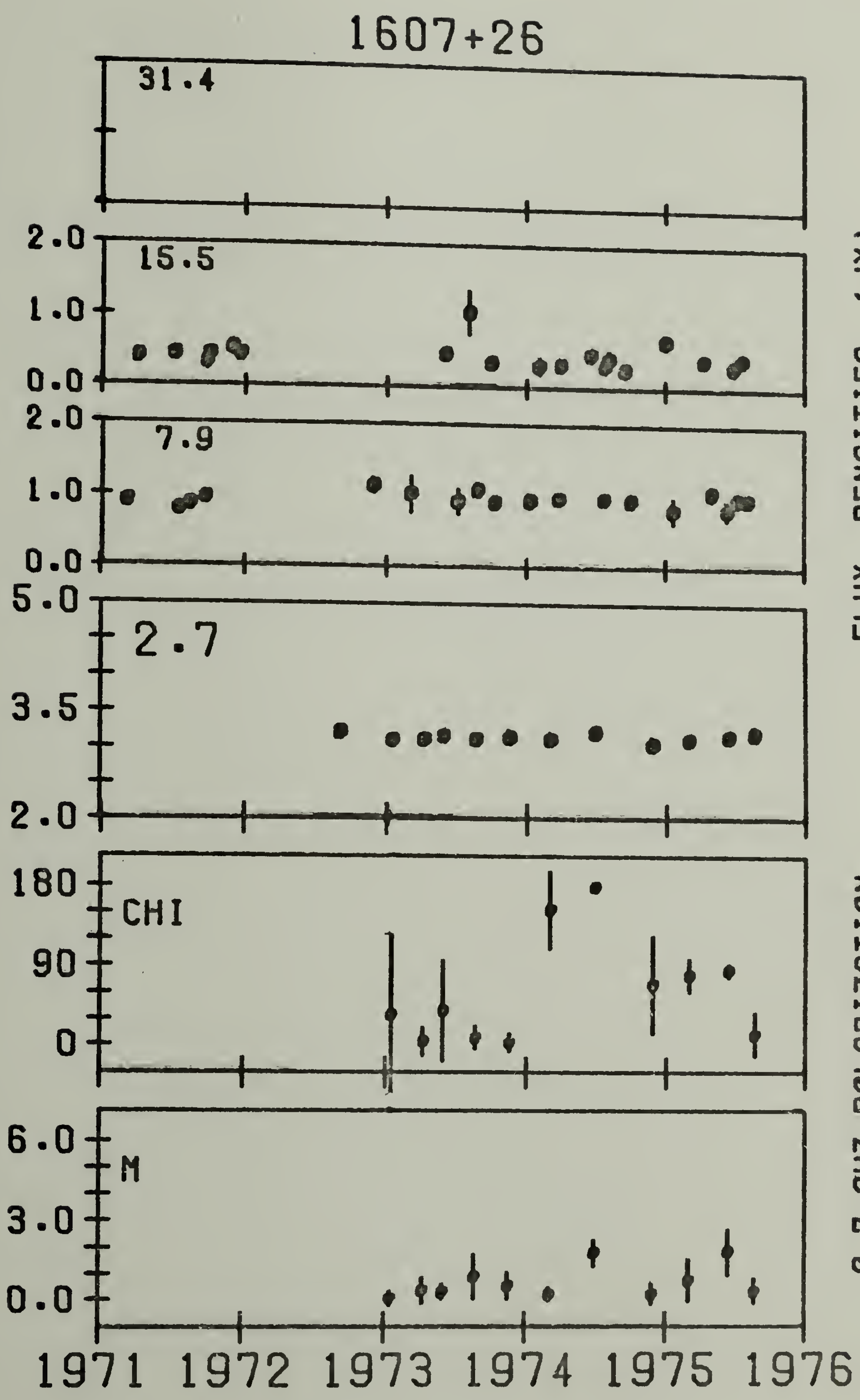
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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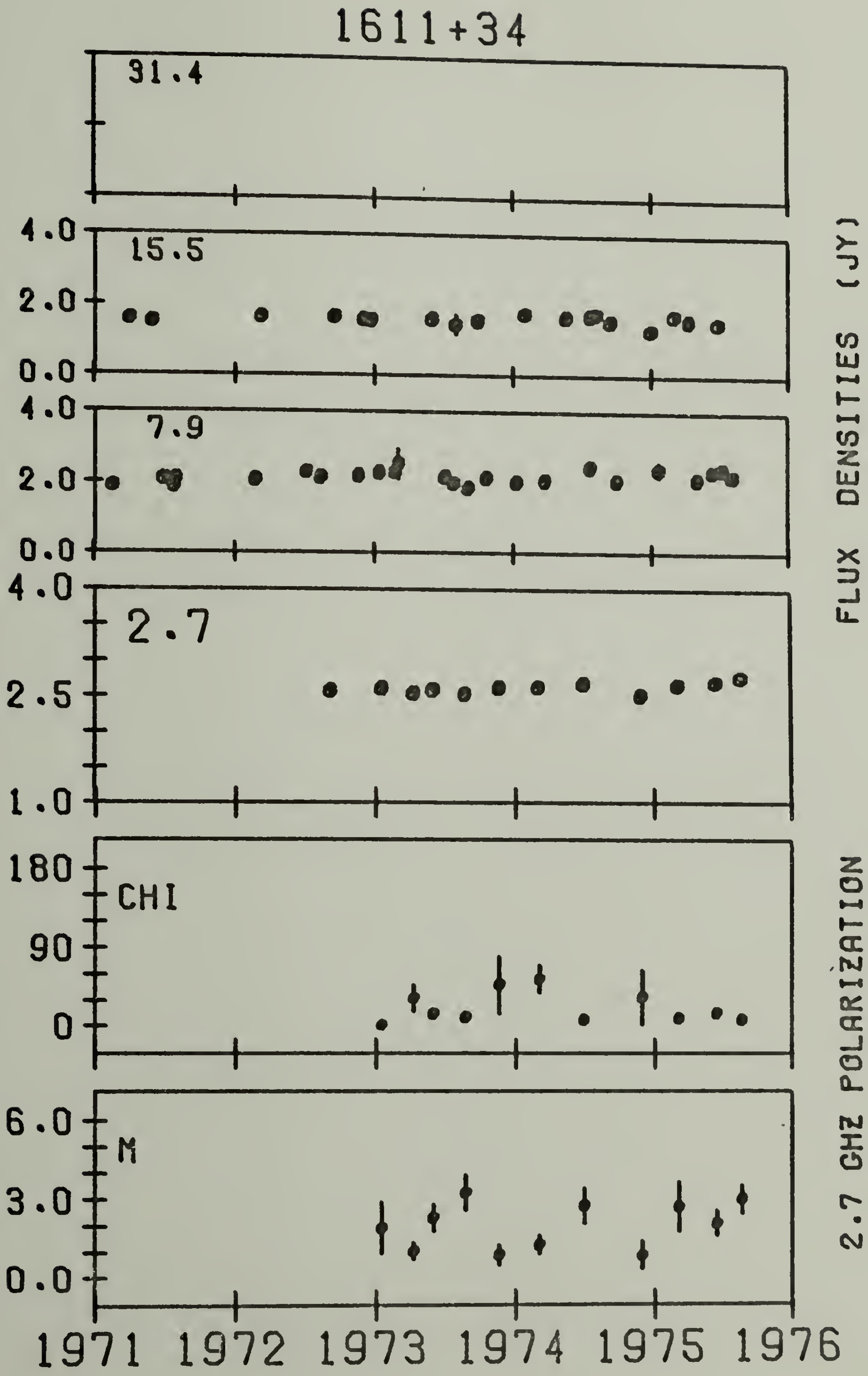
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
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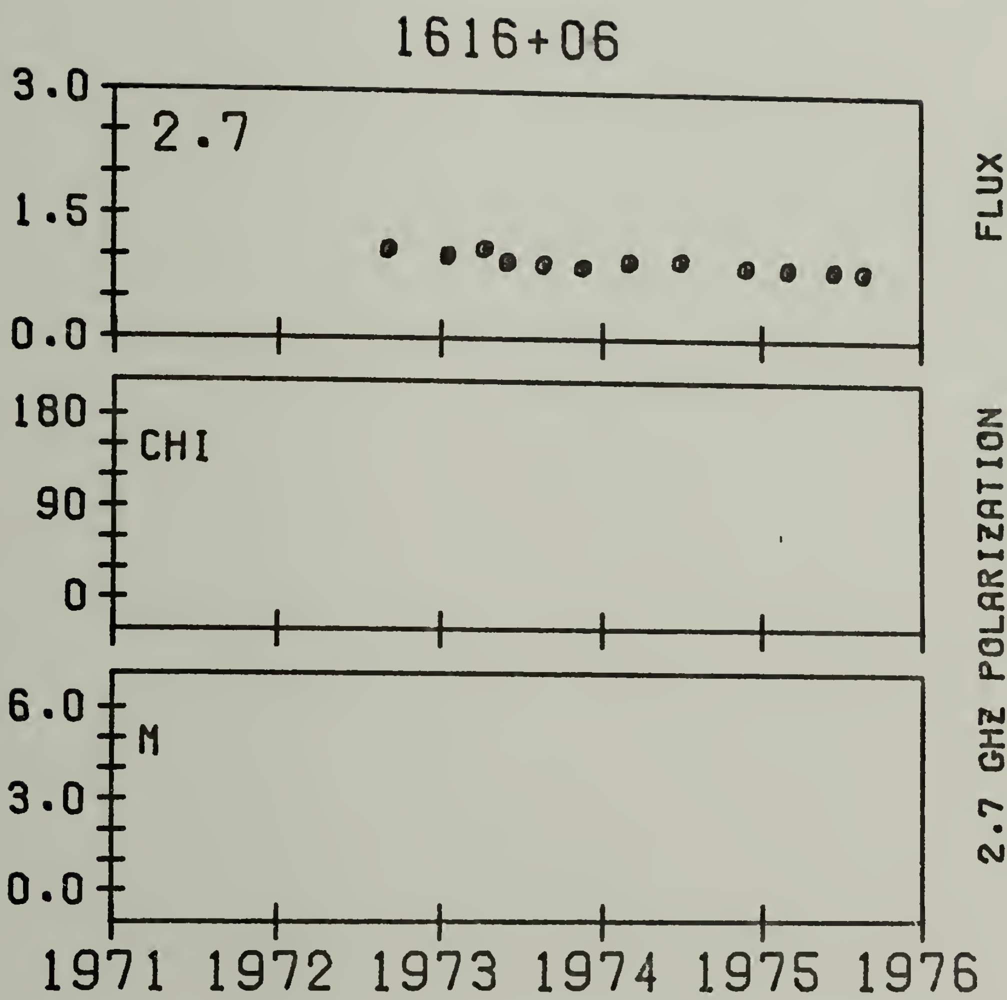

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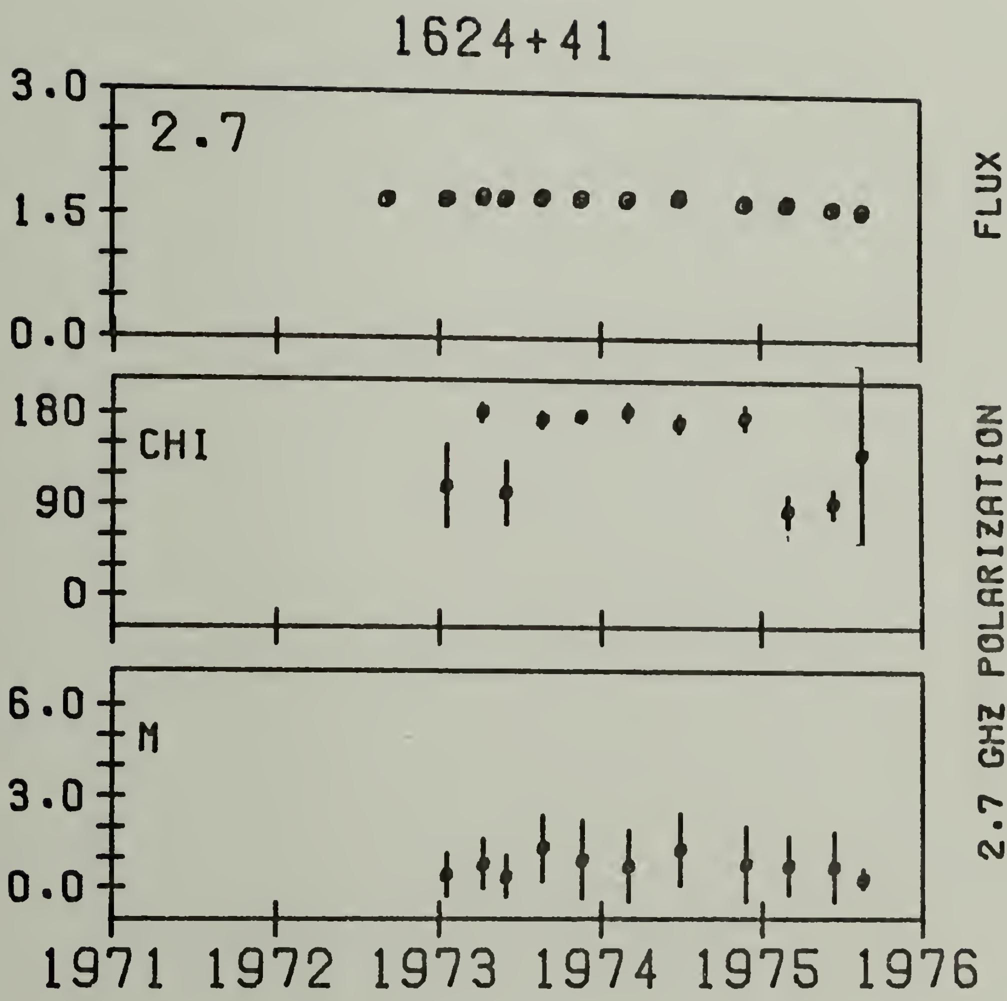

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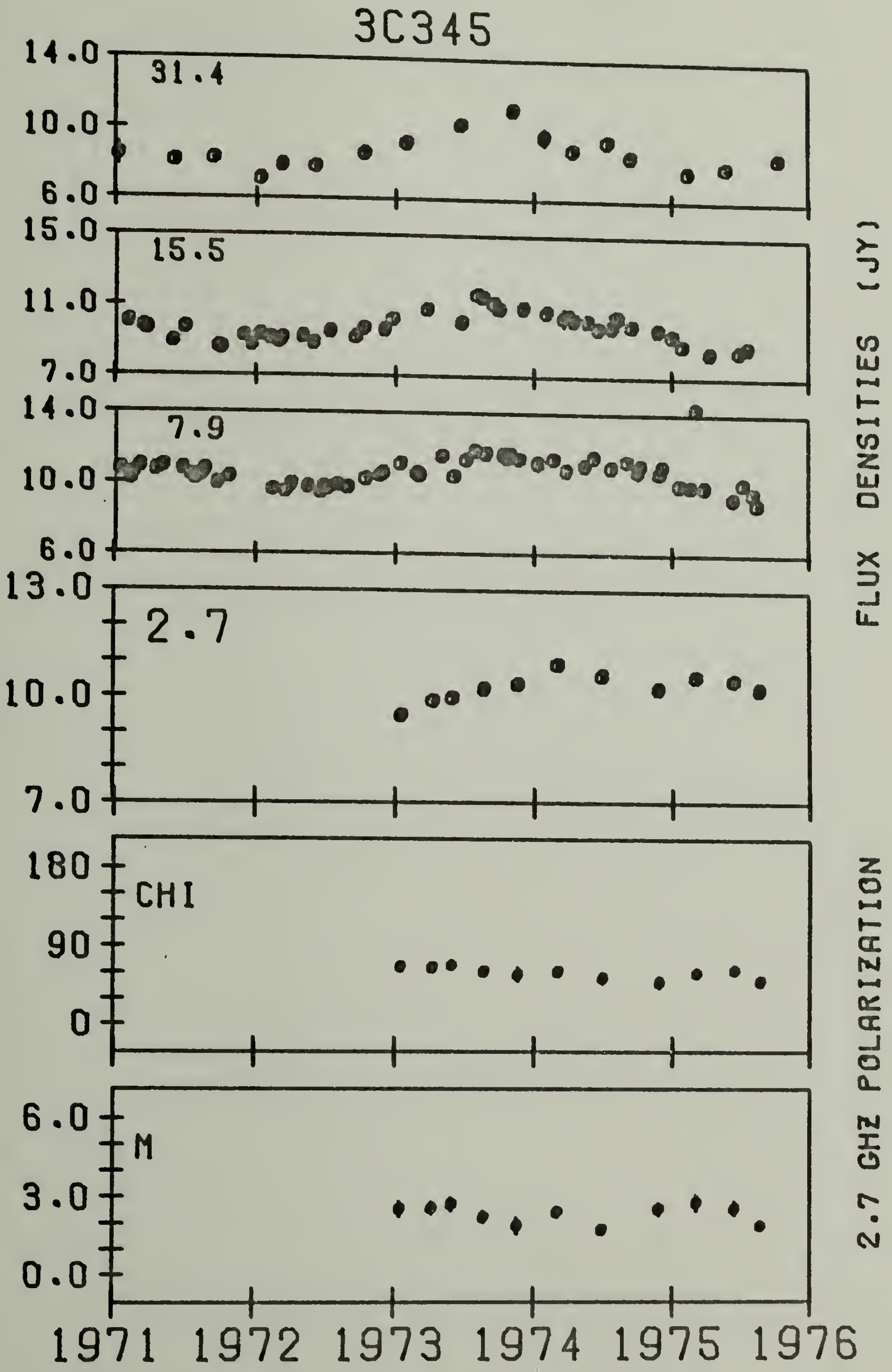
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CHI
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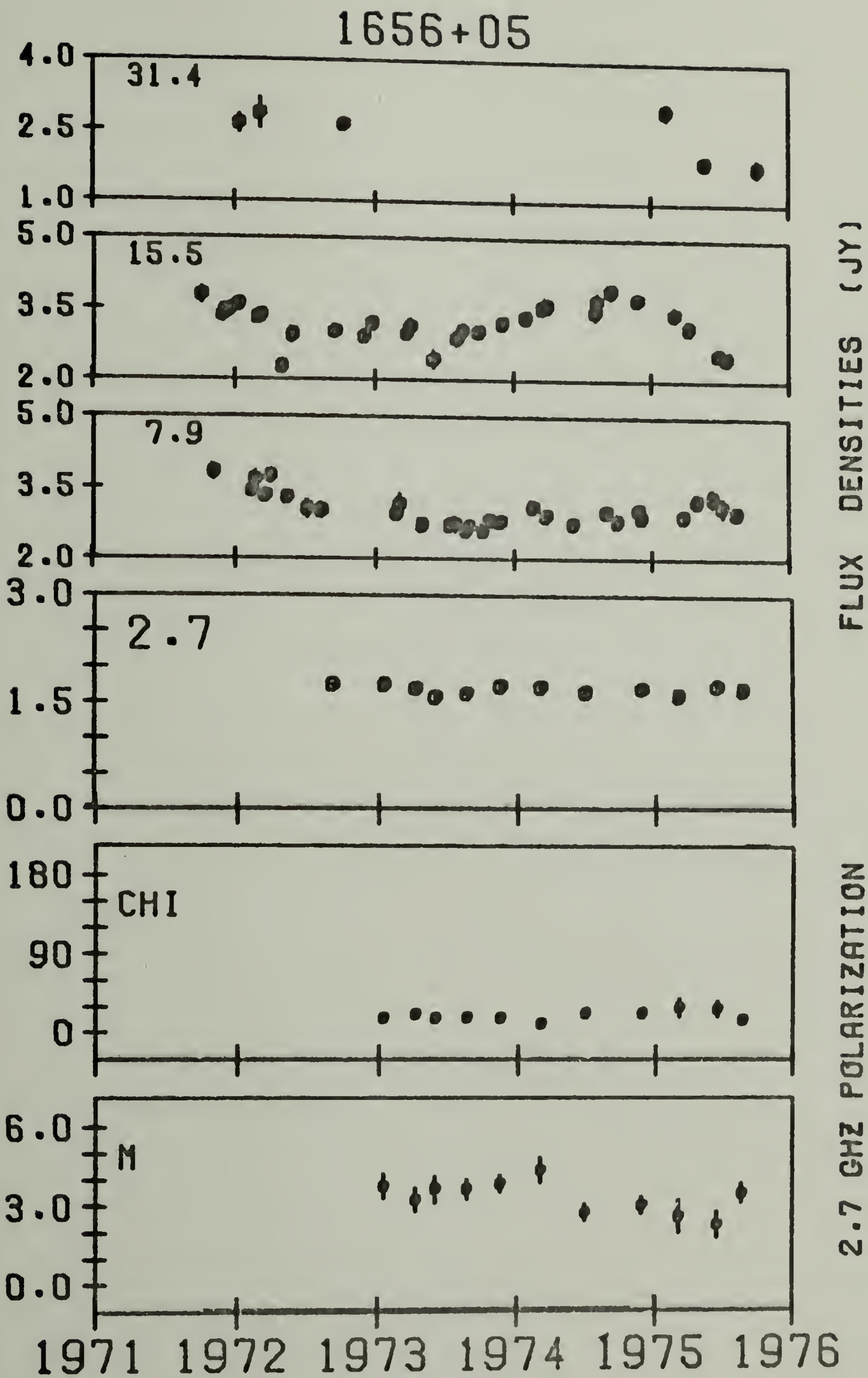
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION



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FLUX DENSITIES (JY)
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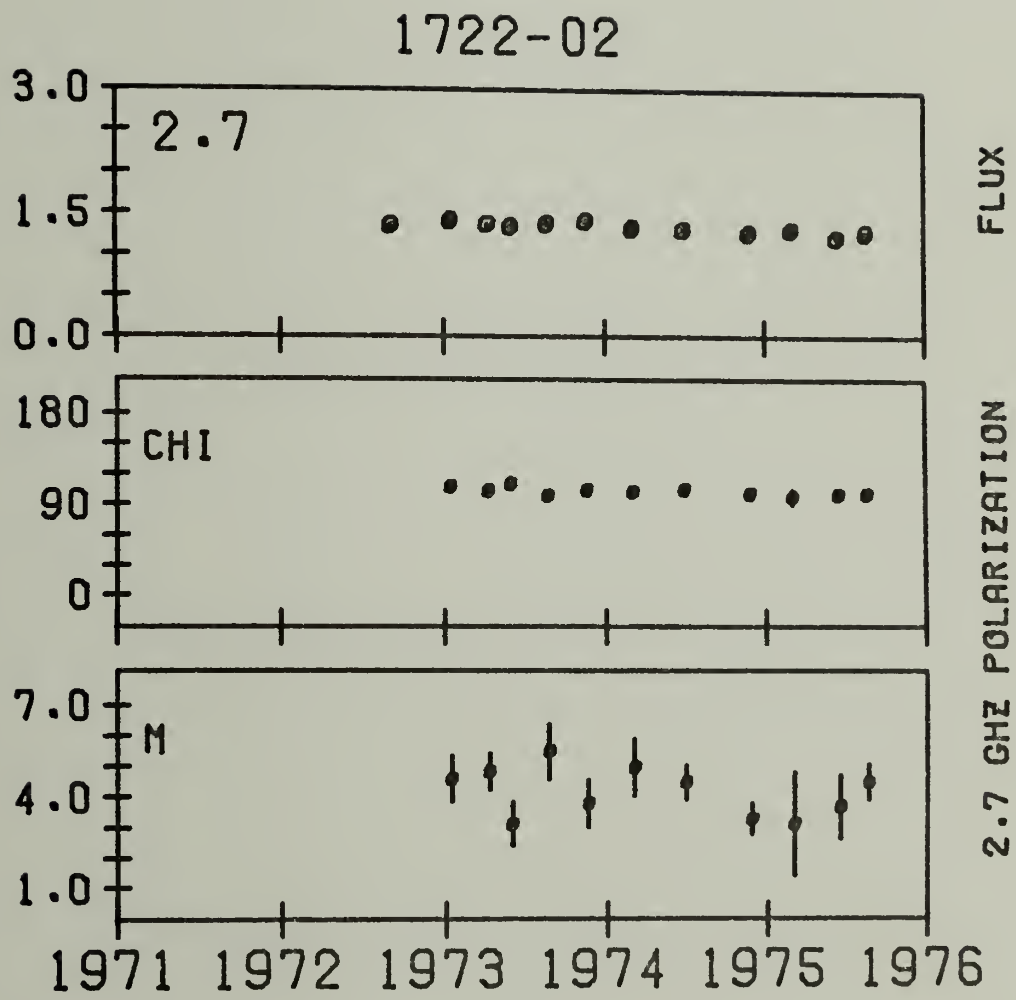

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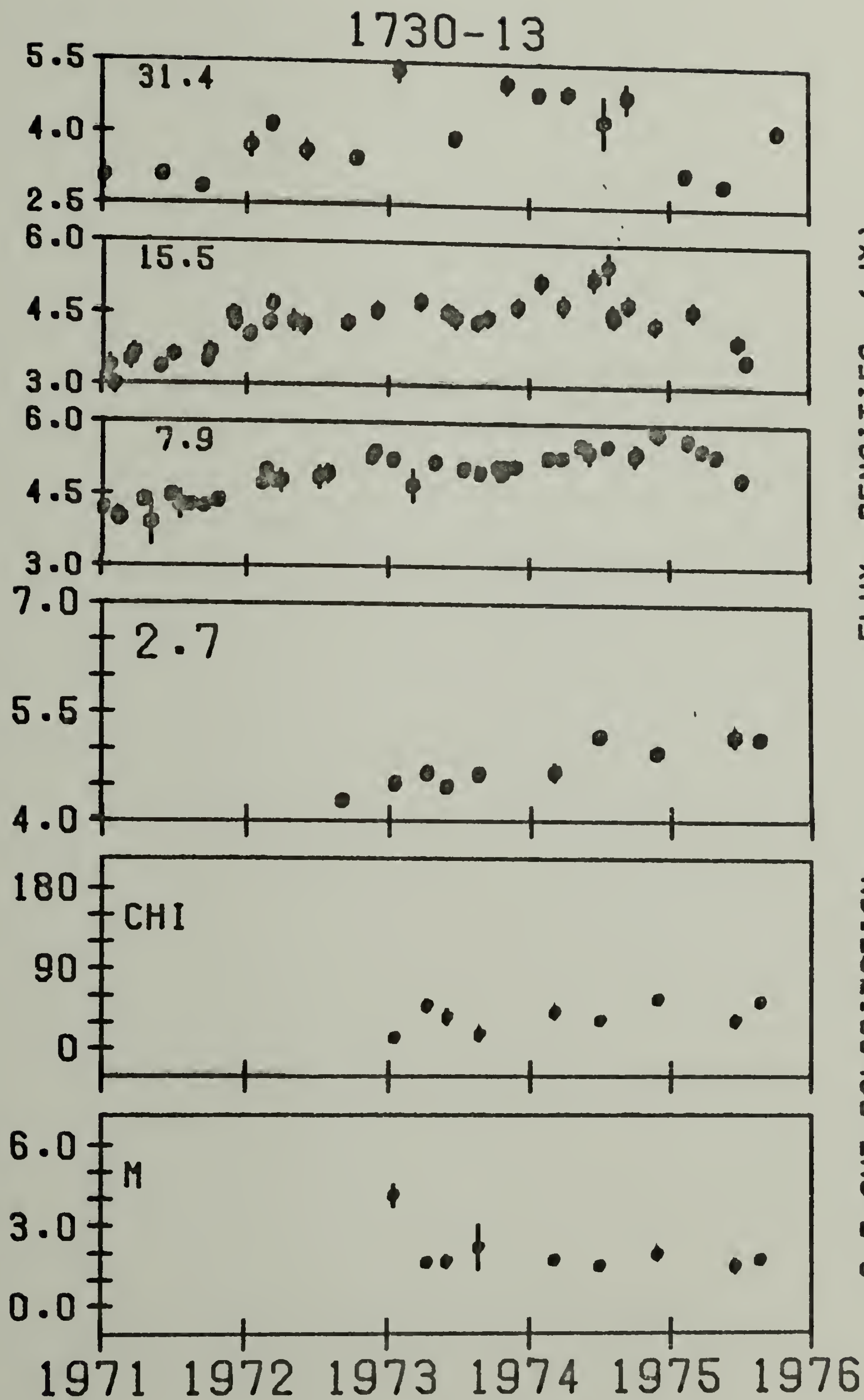
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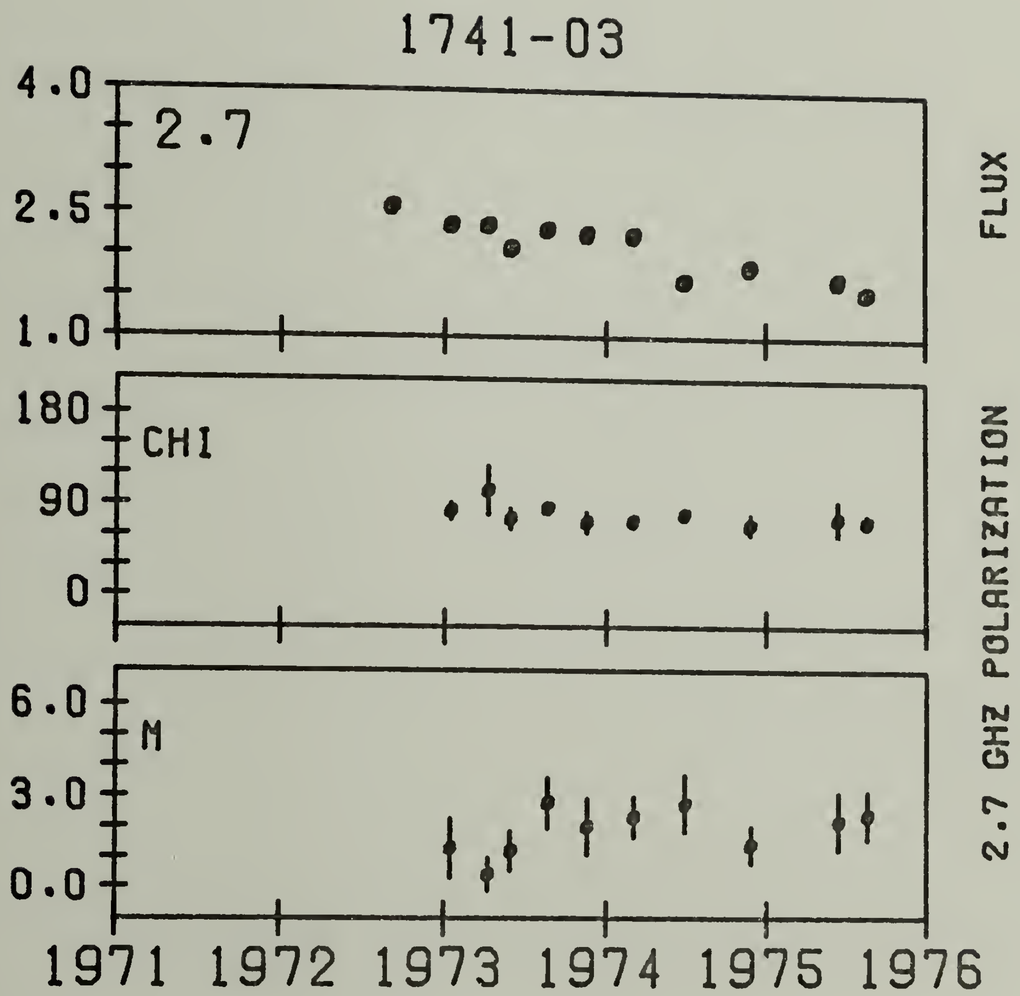
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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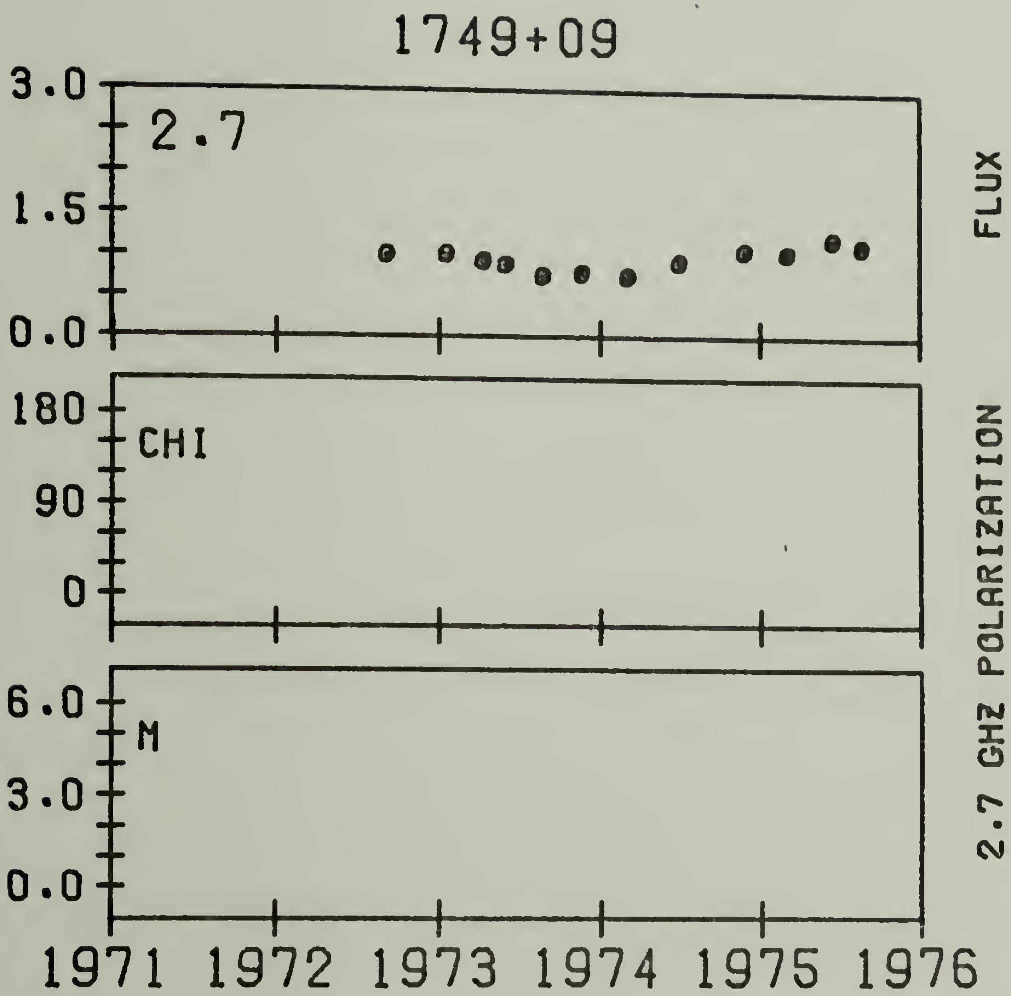

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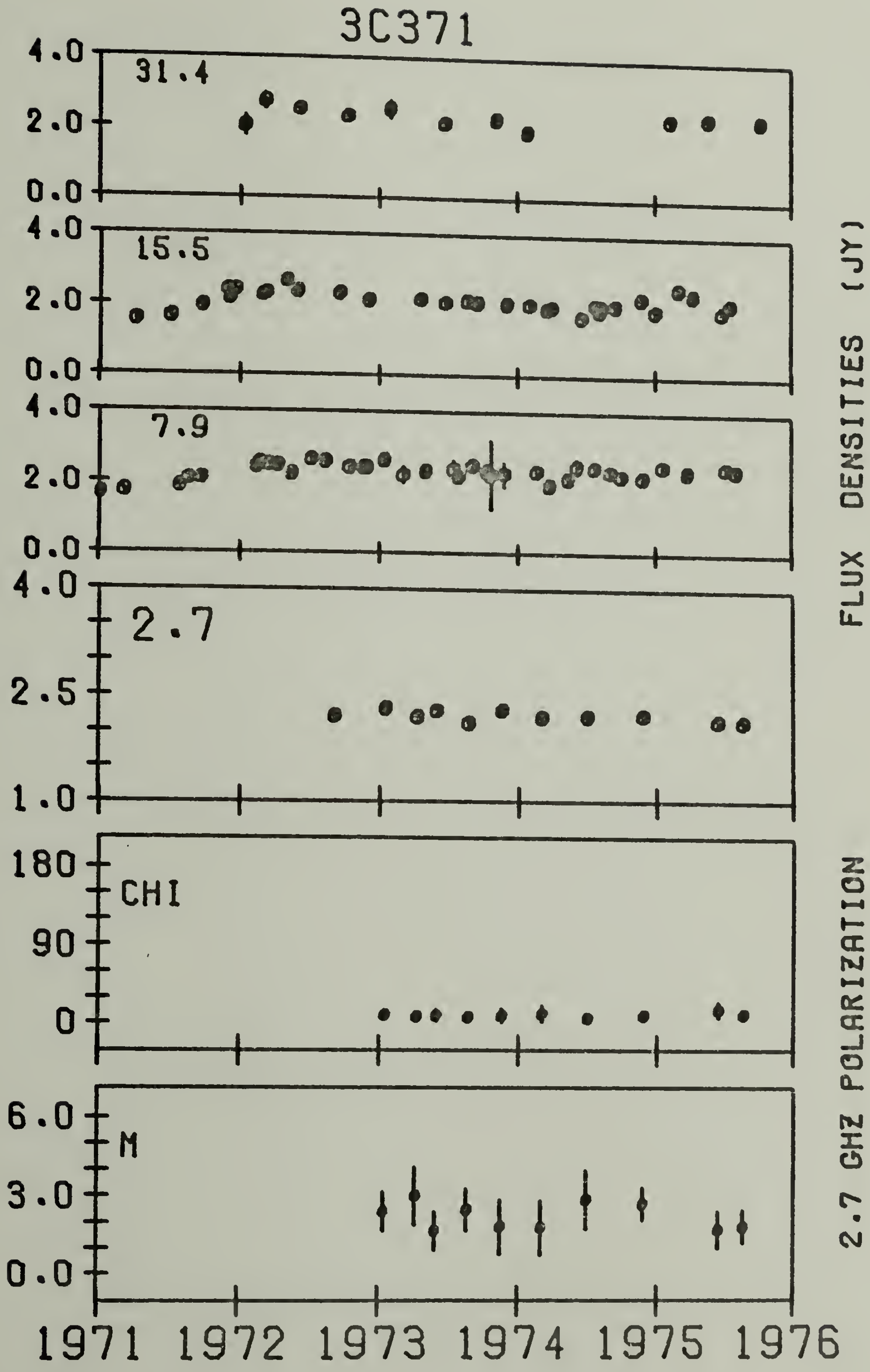
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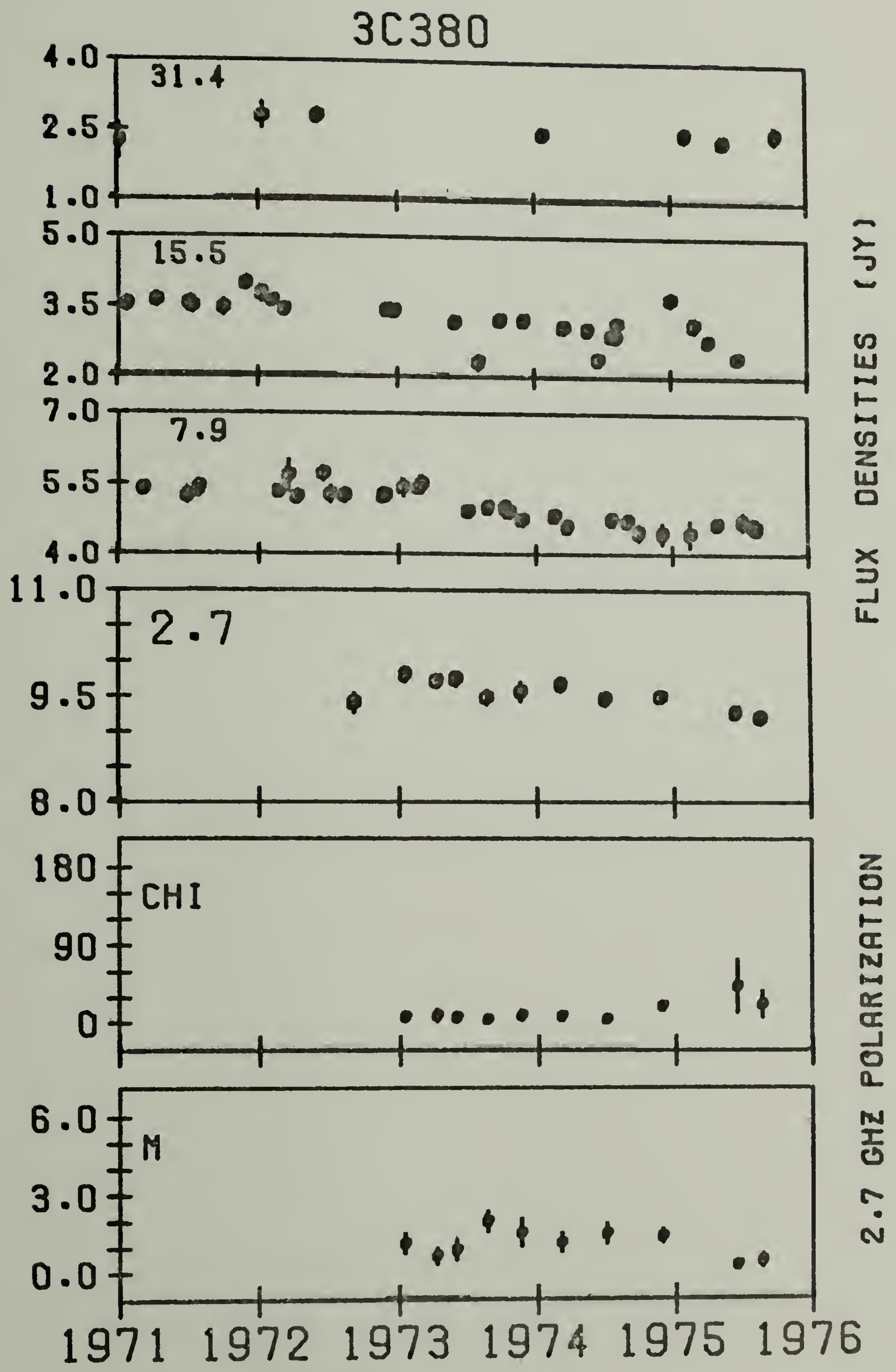
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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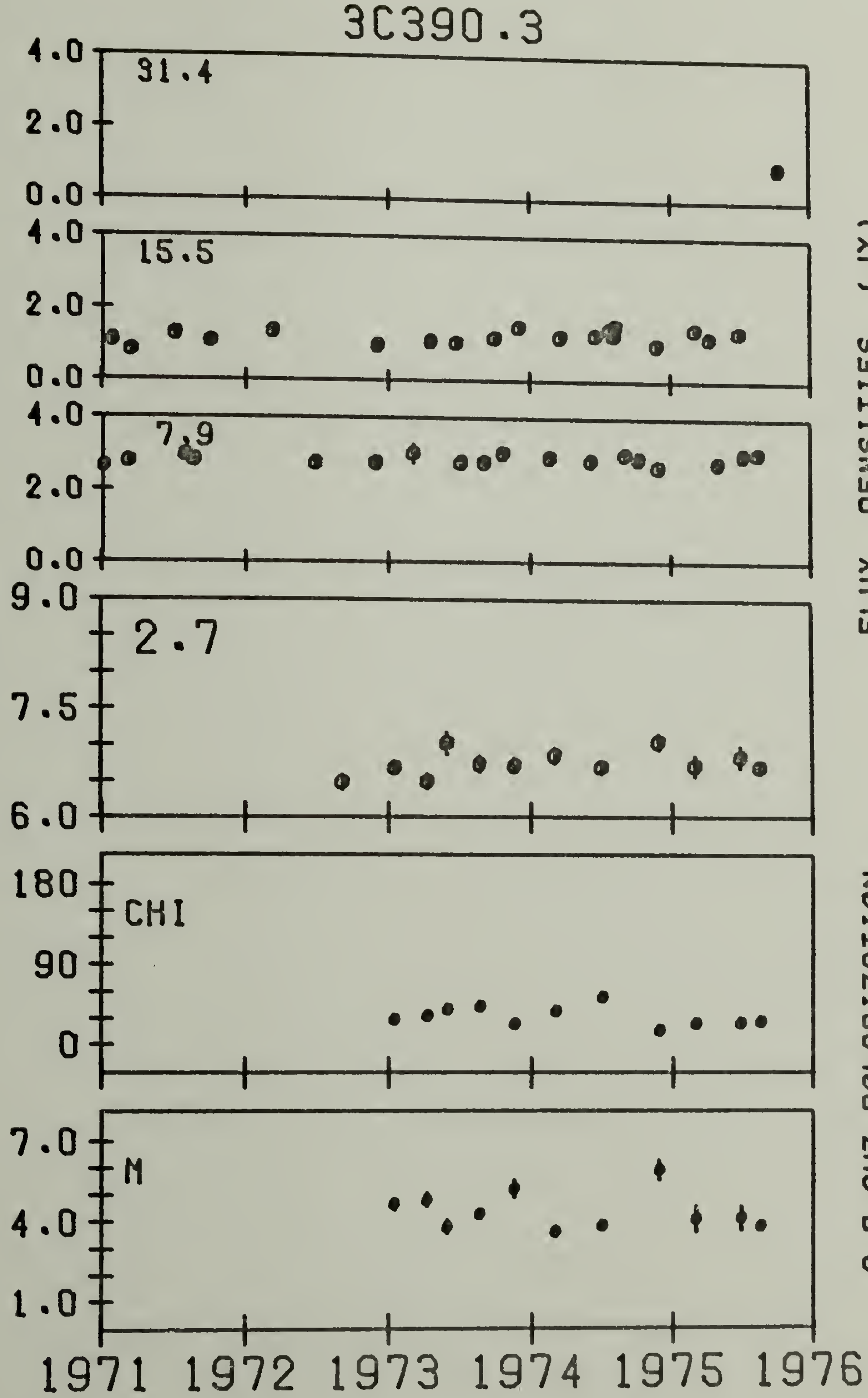
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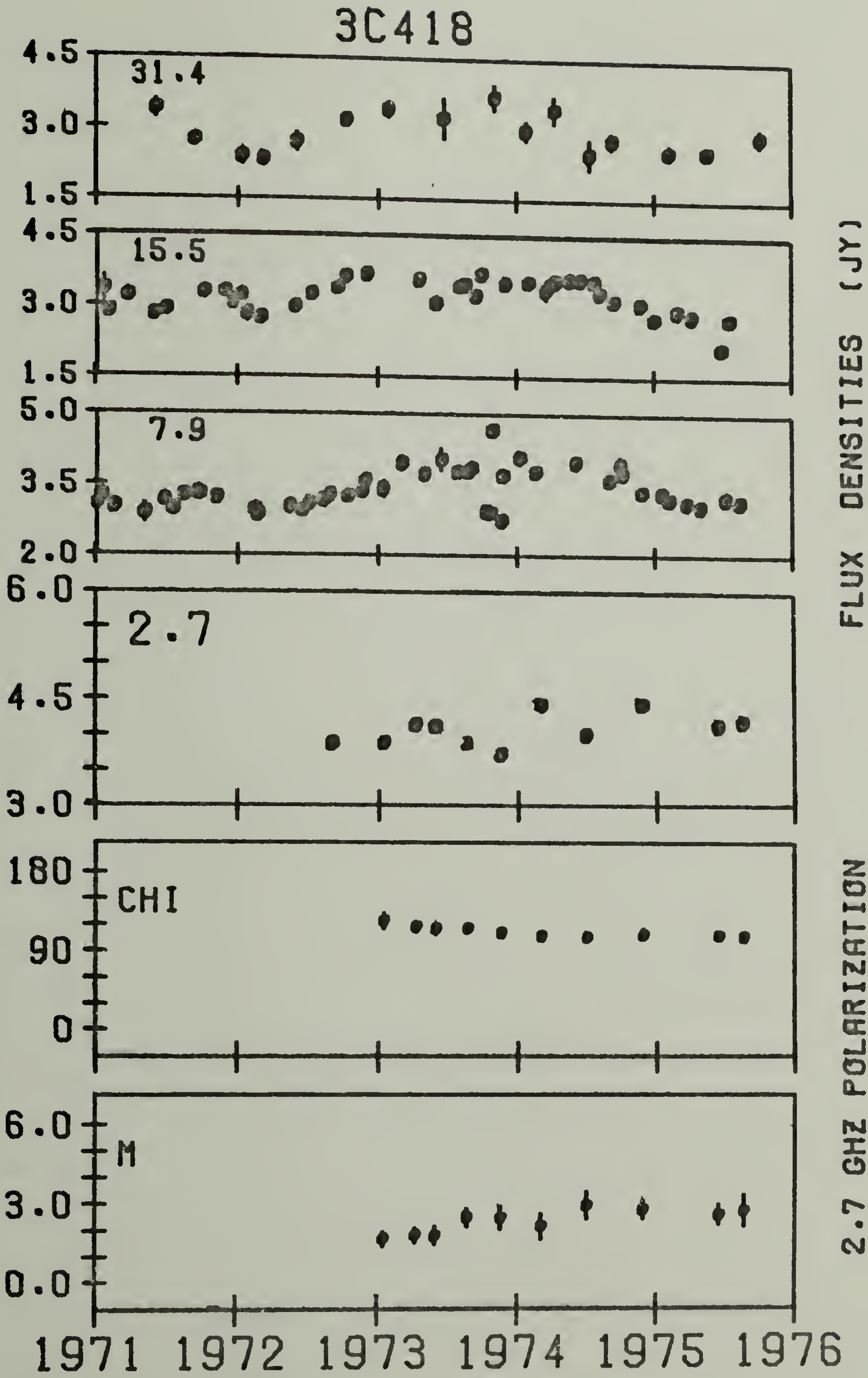
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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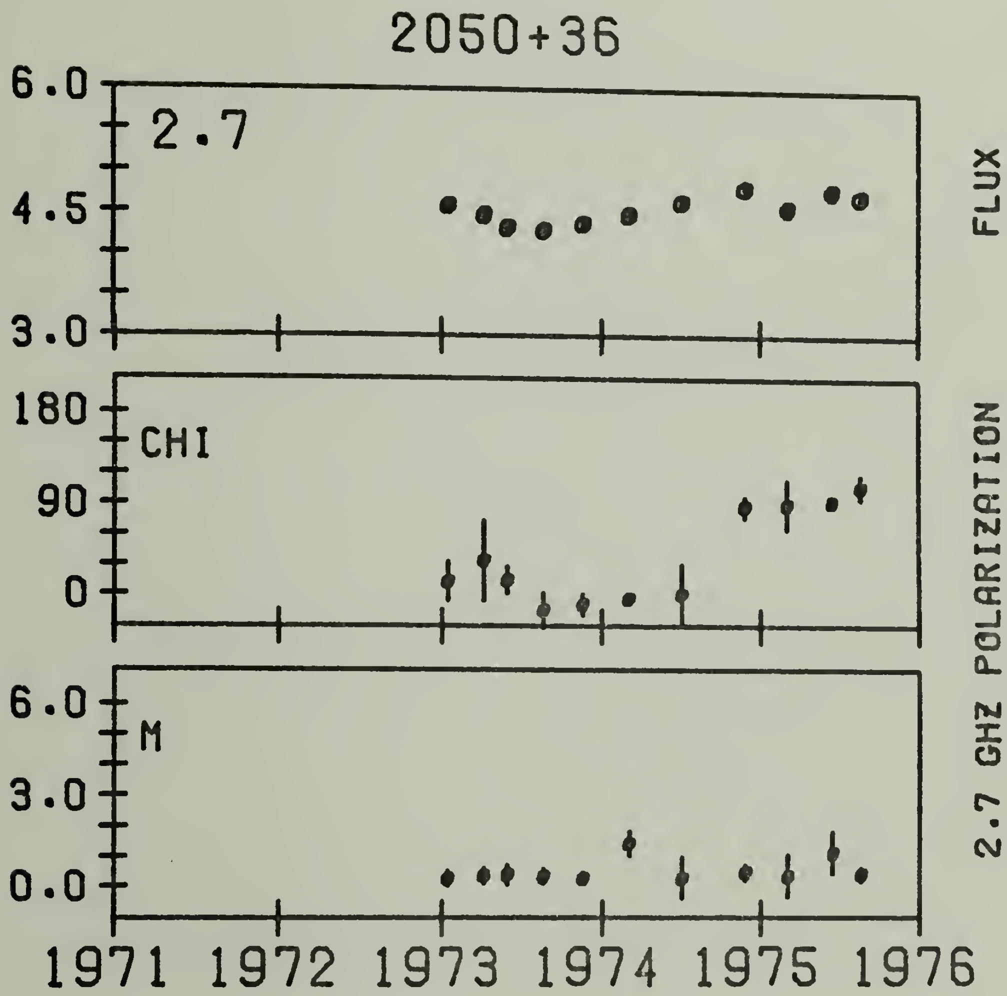
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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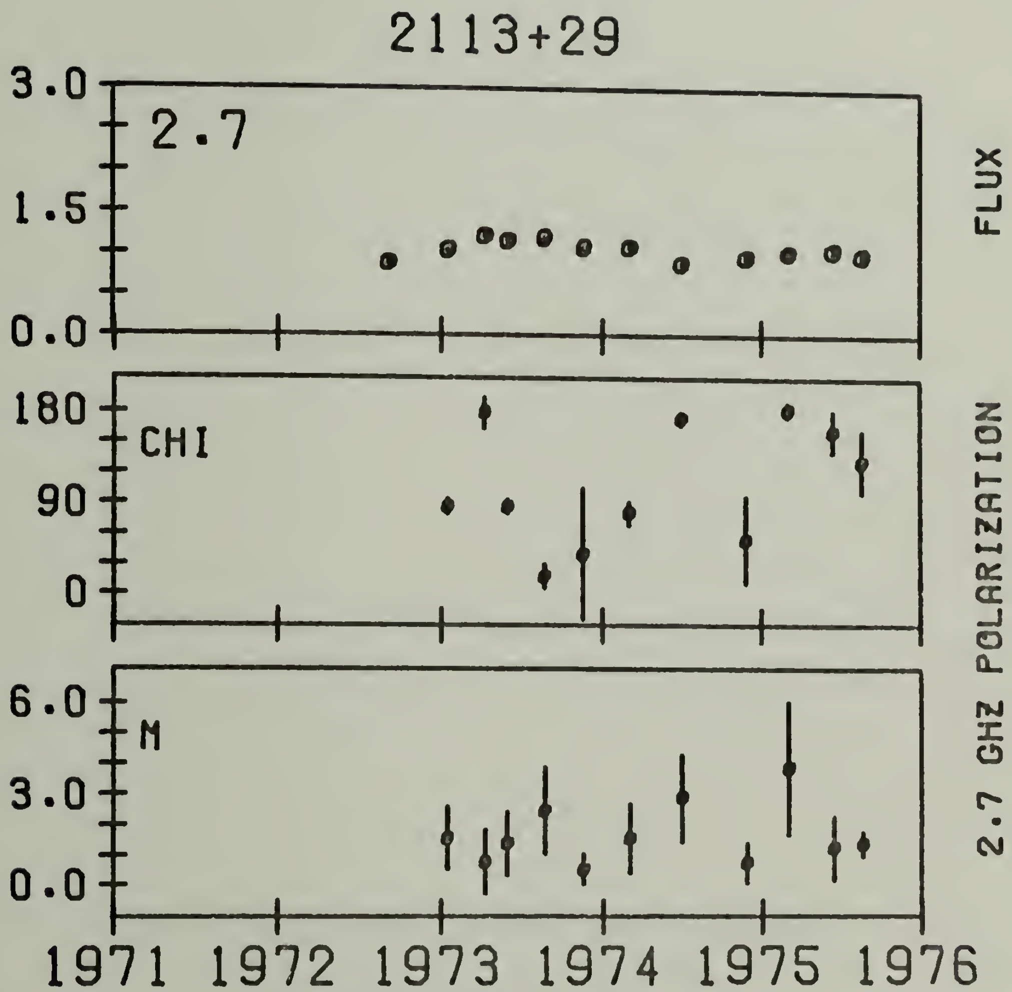
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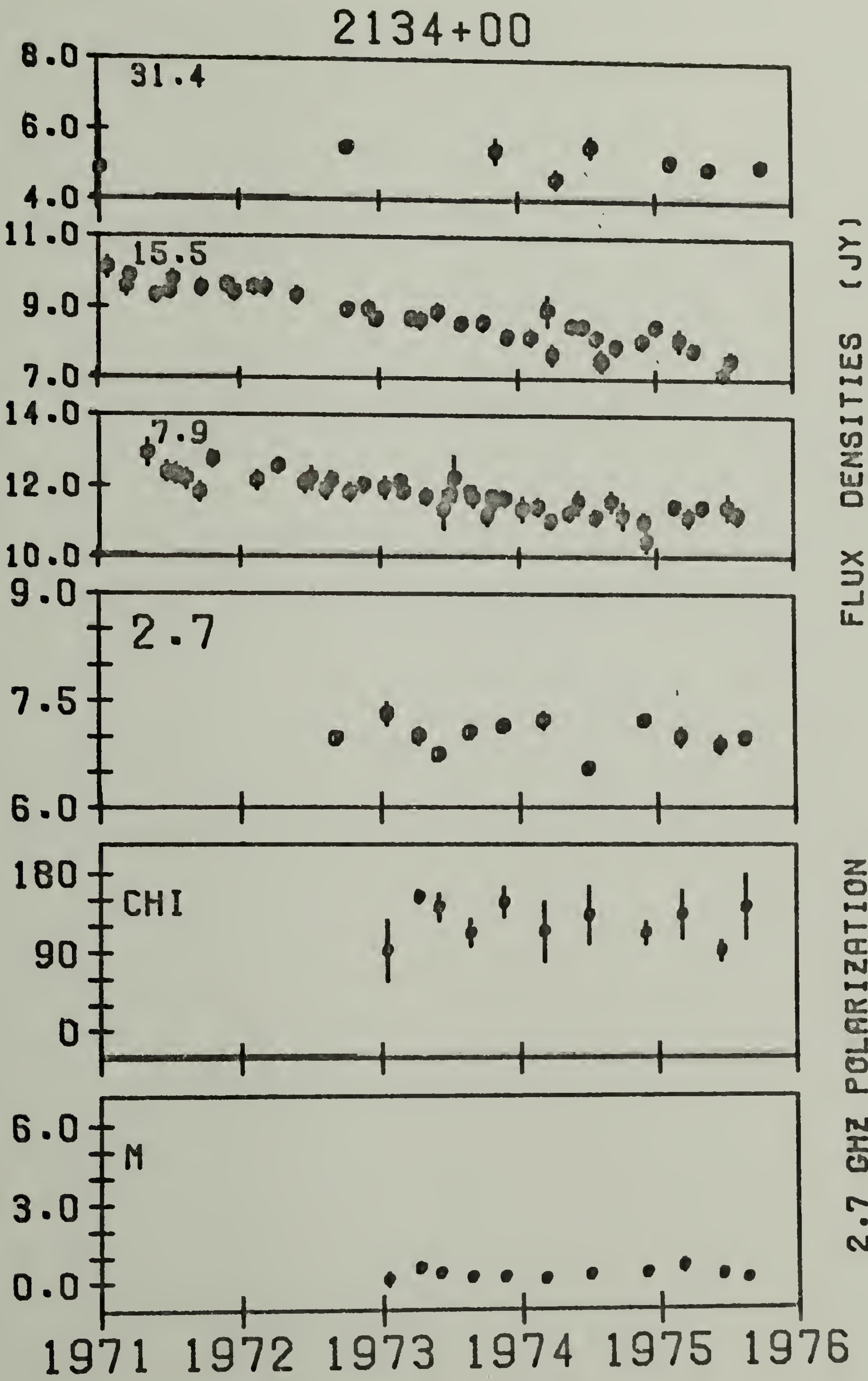
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CHI
M
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2.7 GHZ POLARIZATION
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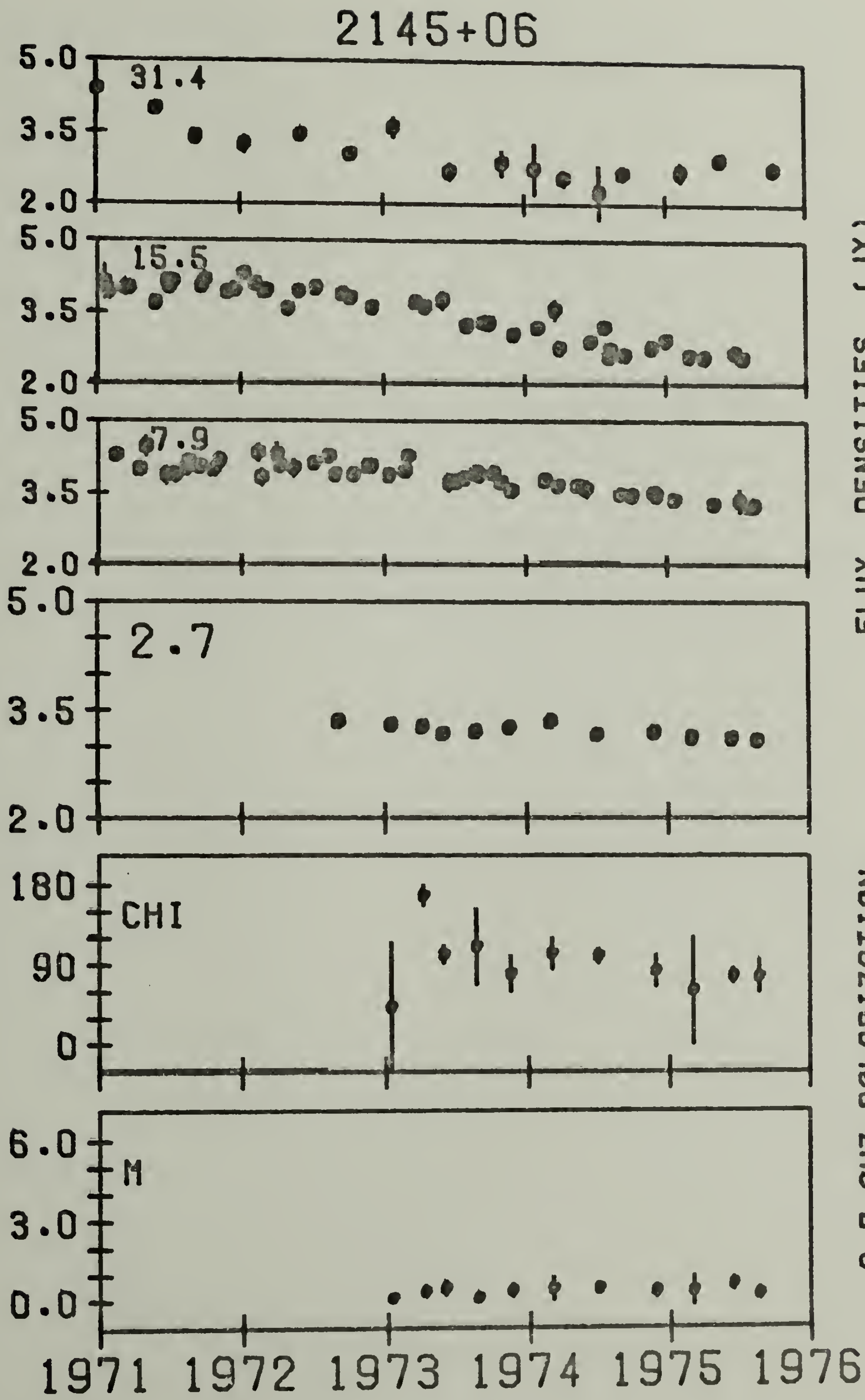
1971 1972 1973 1974 1975 1976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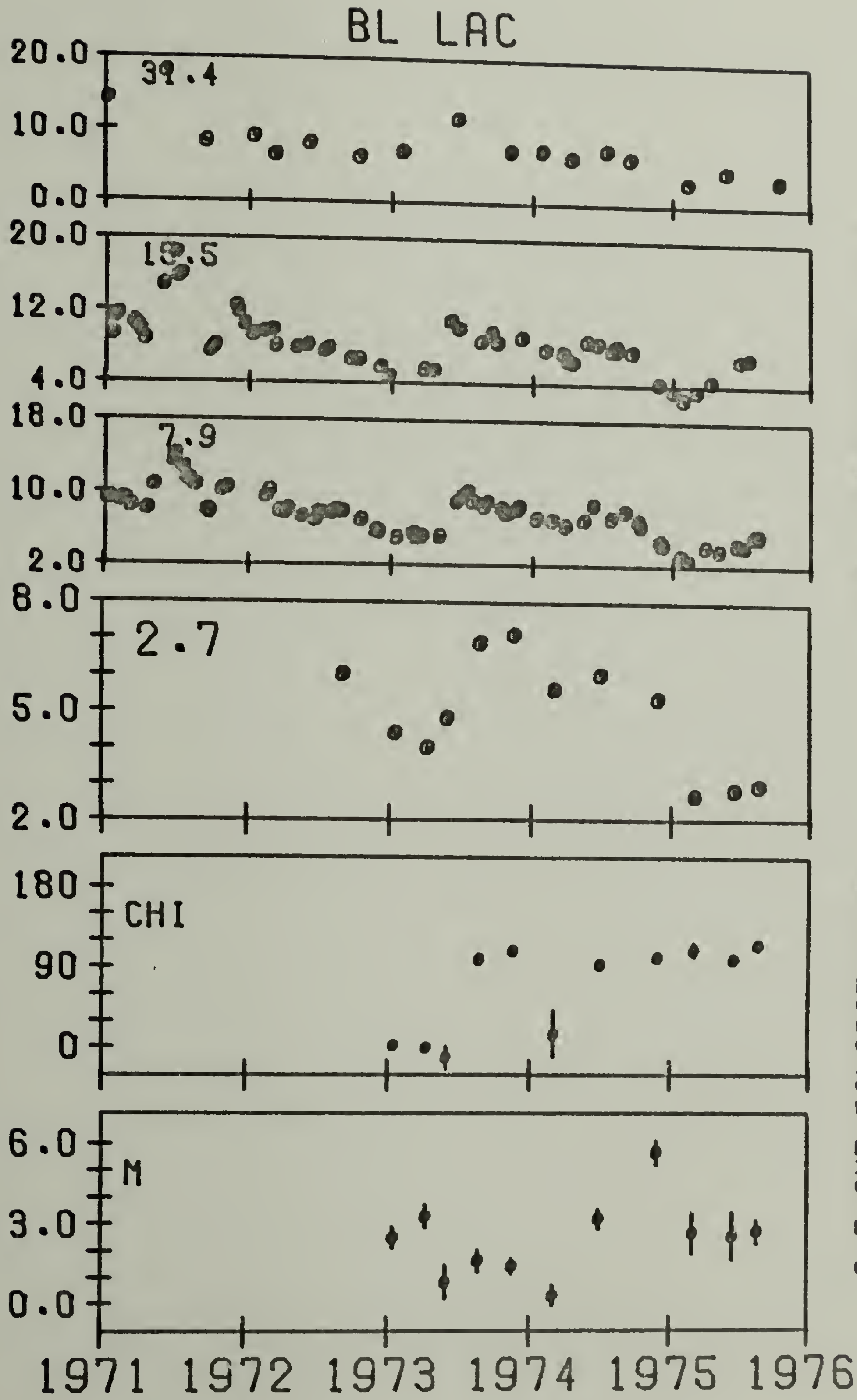
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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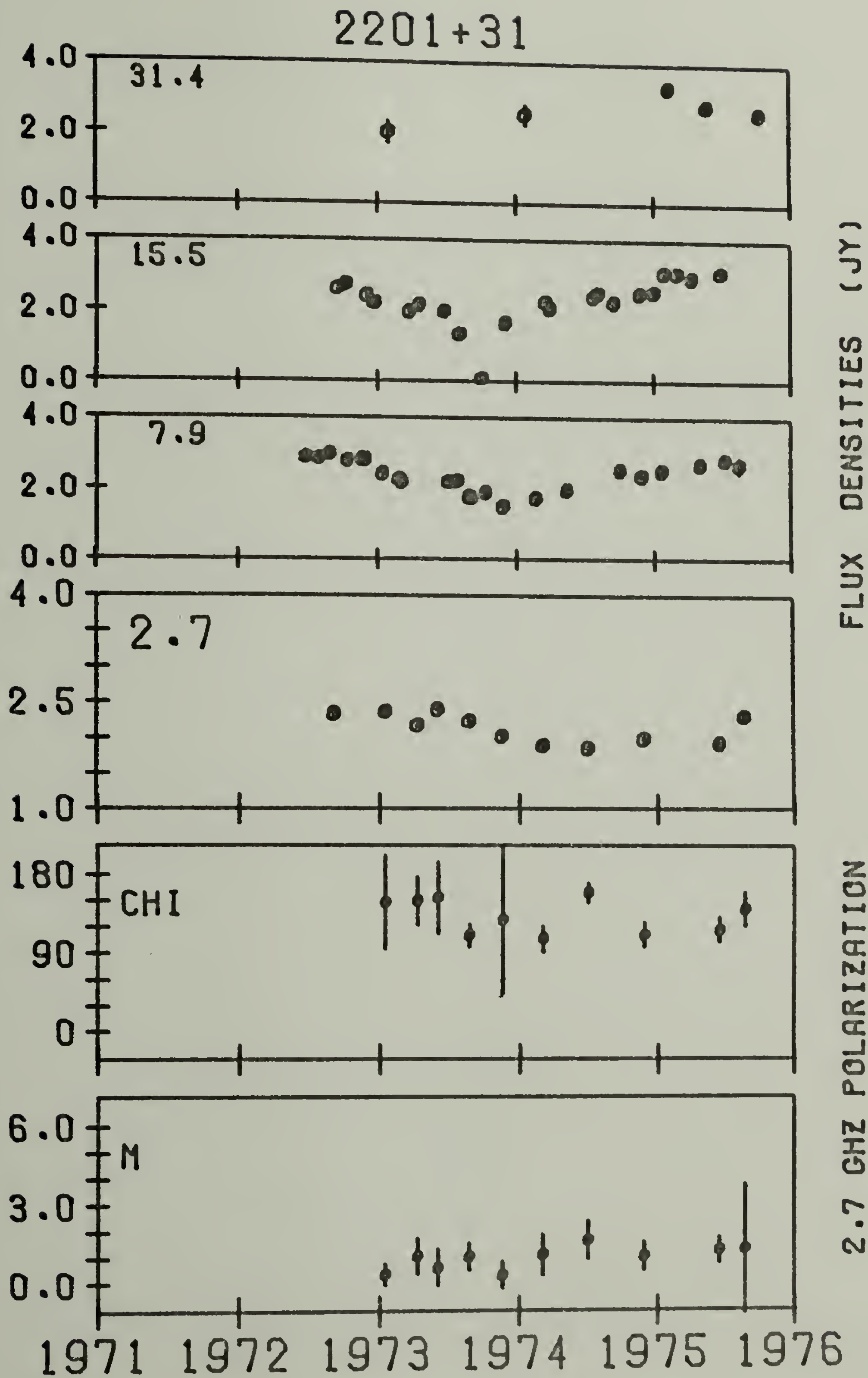
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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CHI
M
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION
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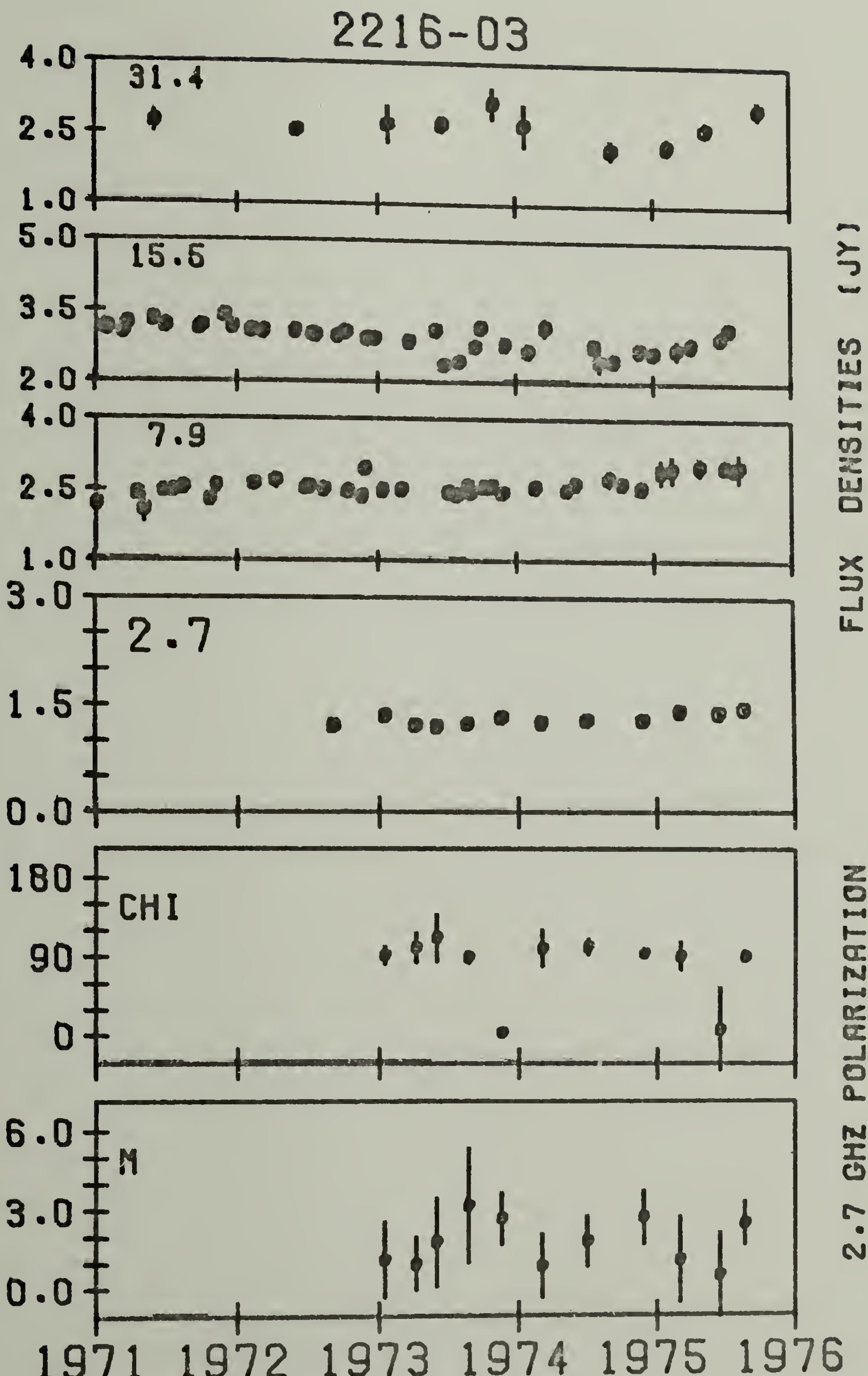

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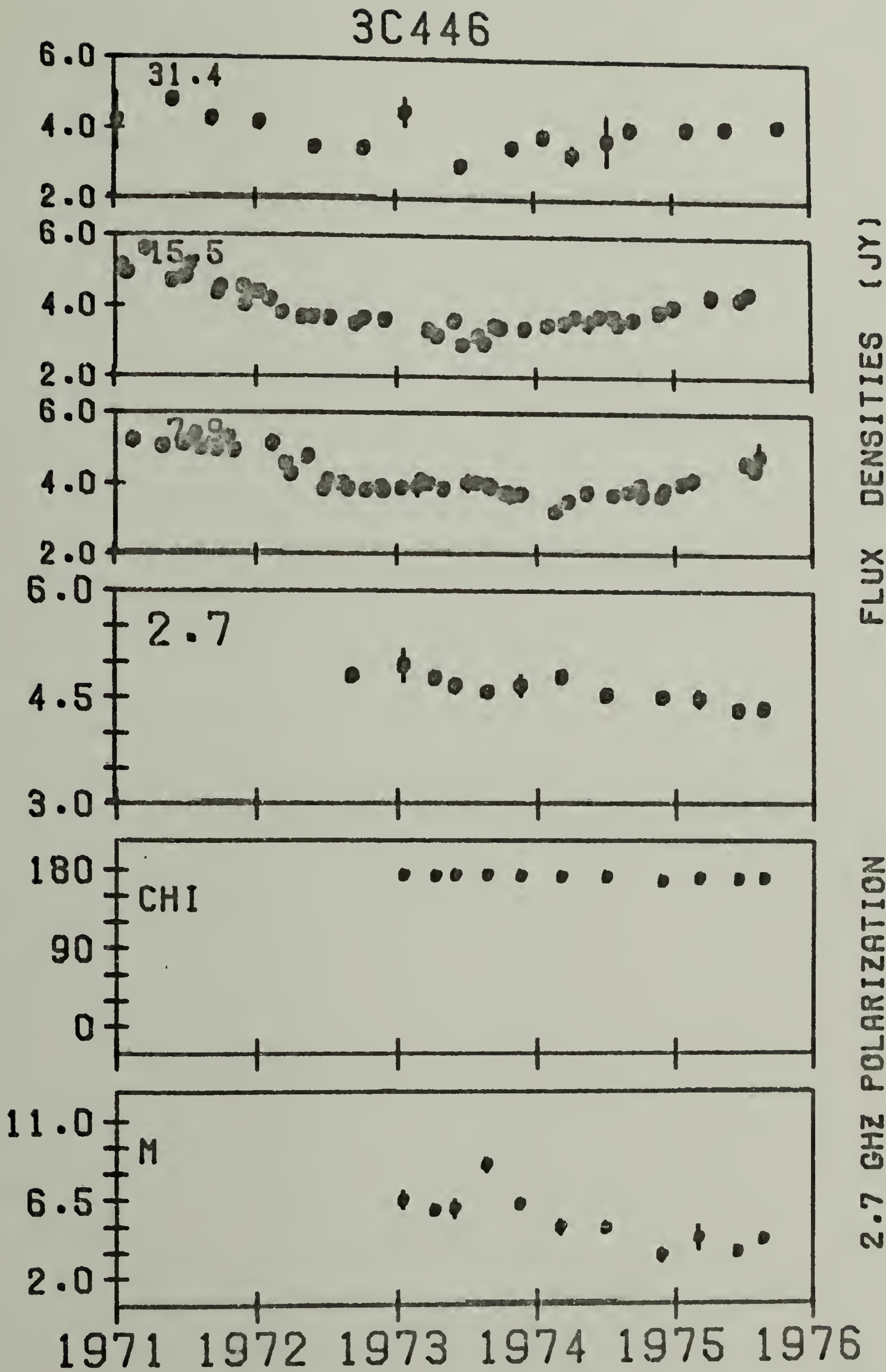
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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CHI
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2.7 GHZ POLARIZATION
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1972
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1975
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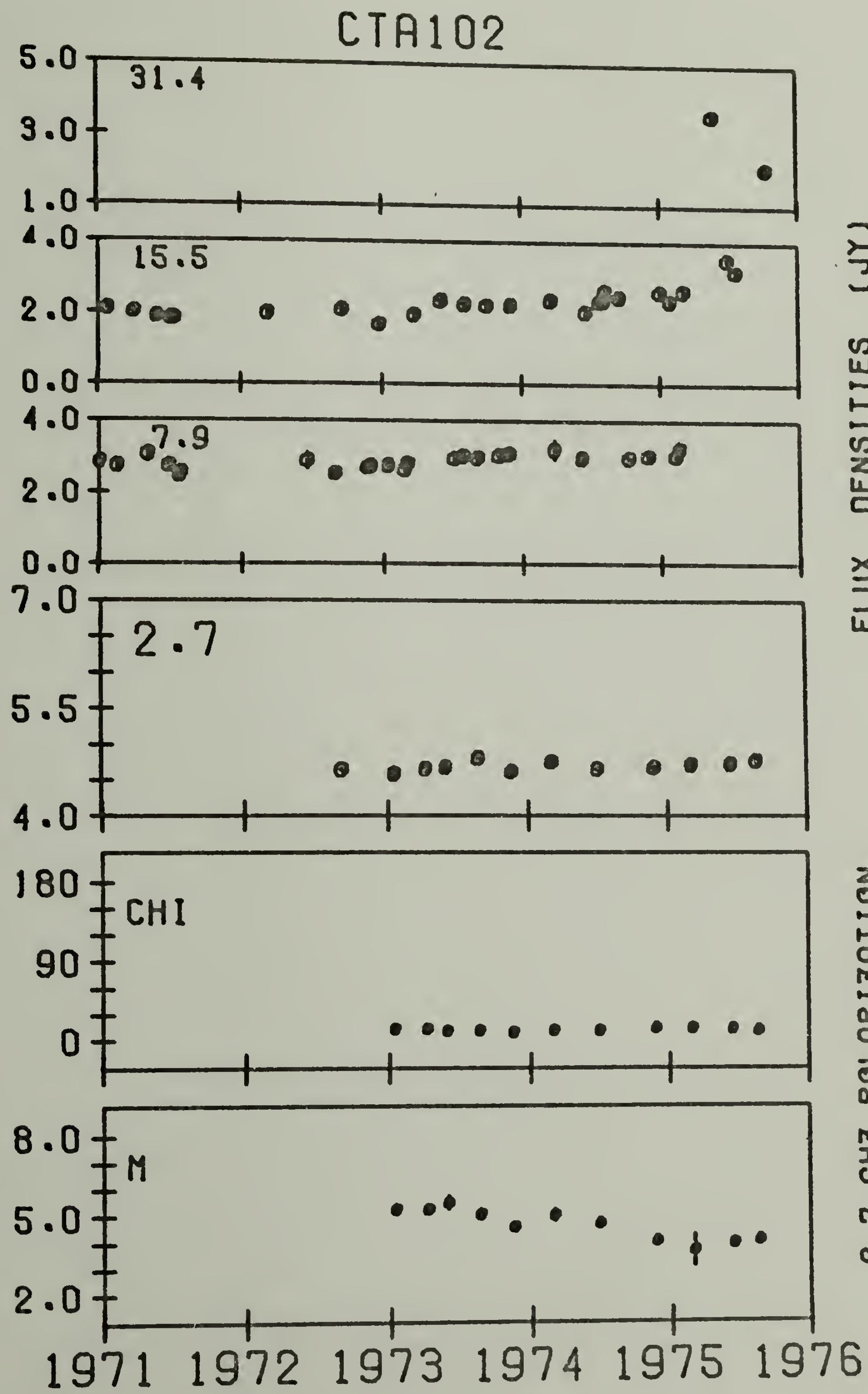
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7.0
5.5
4.0
2.7
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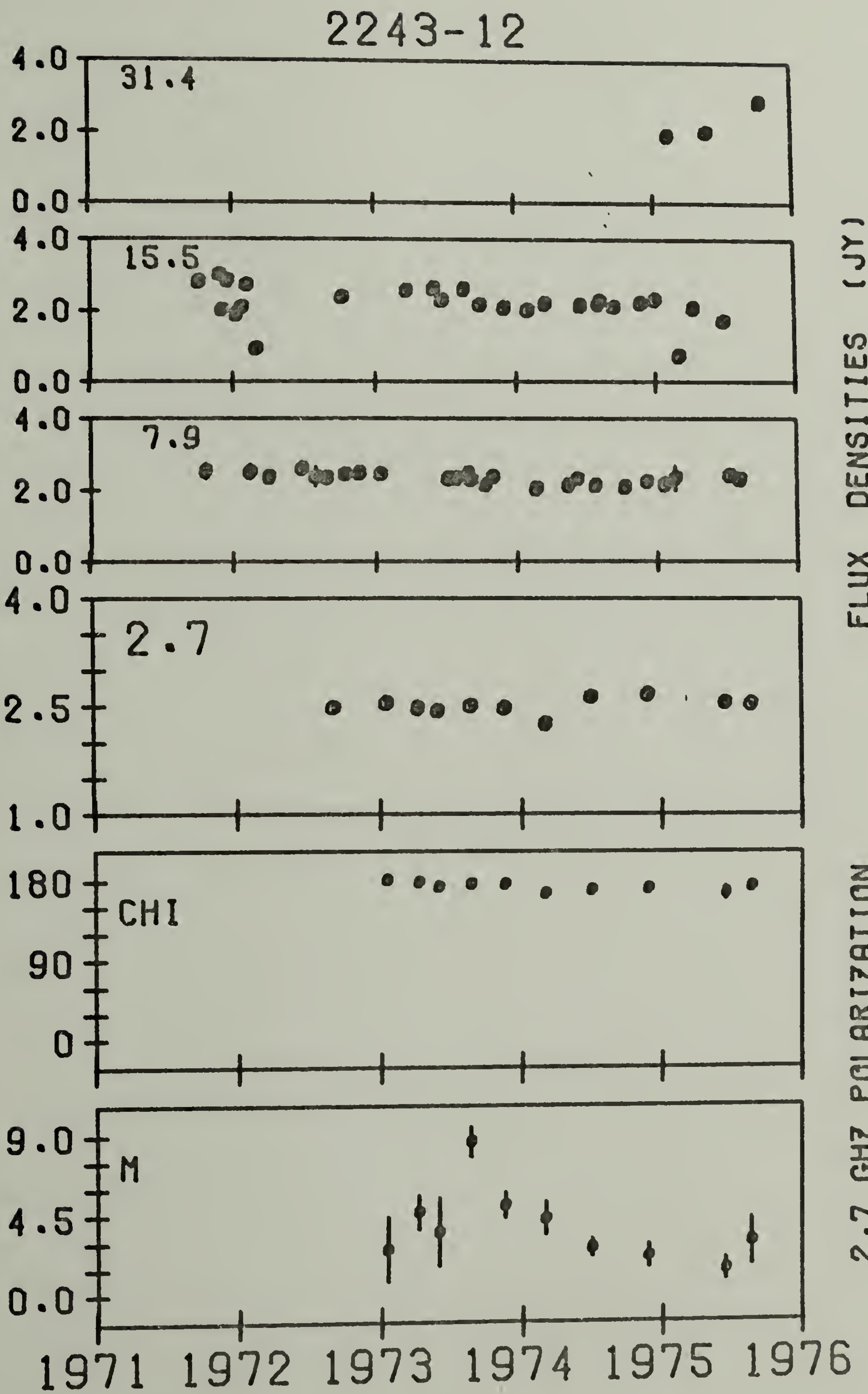
CHI
8.0
5.0
2.0
M
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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CHI
M
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0.0
2.5
1.0
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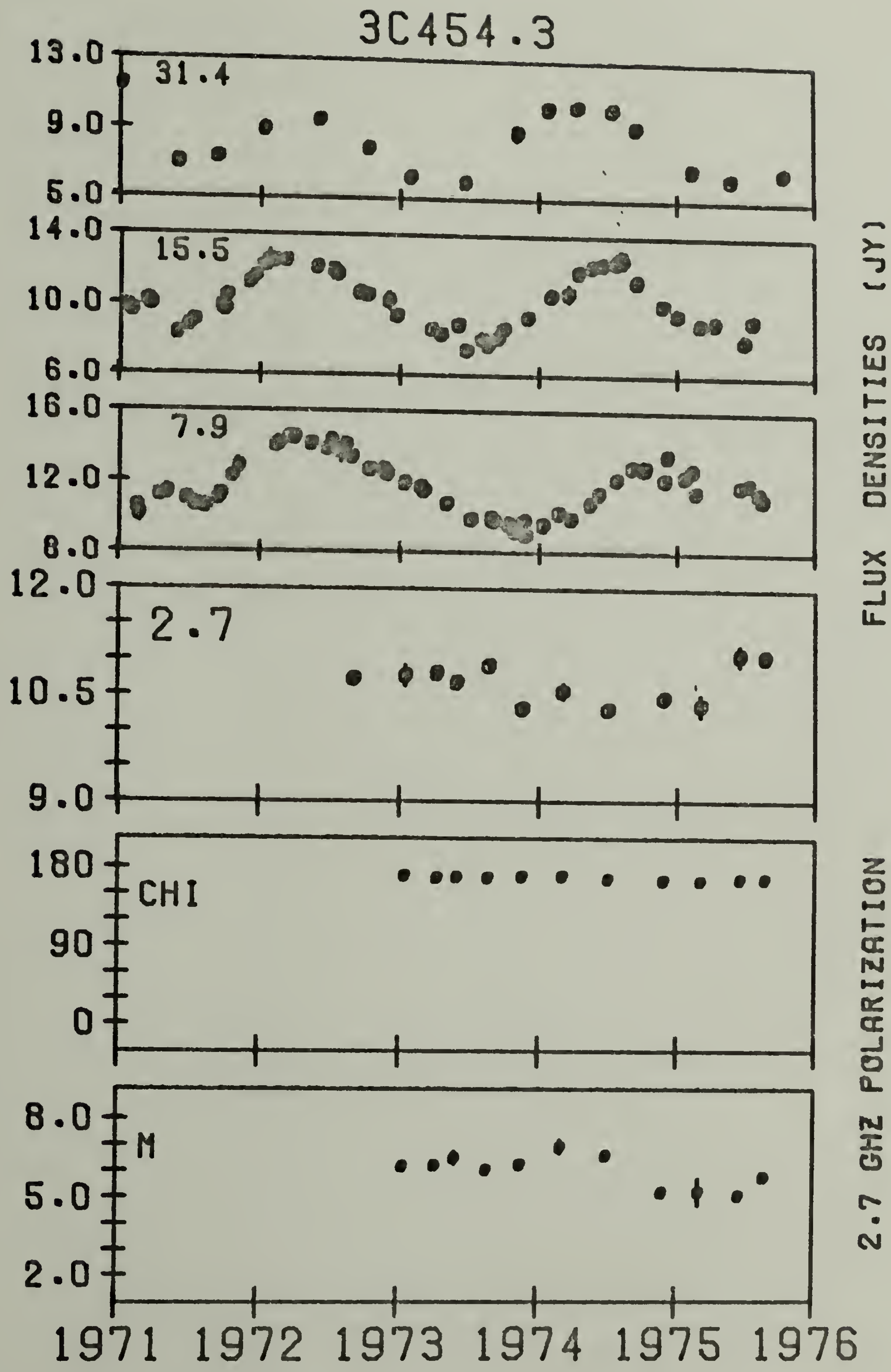
9.0
4.5
1971
1972
1973
1974
1975
1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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12.0
10.5
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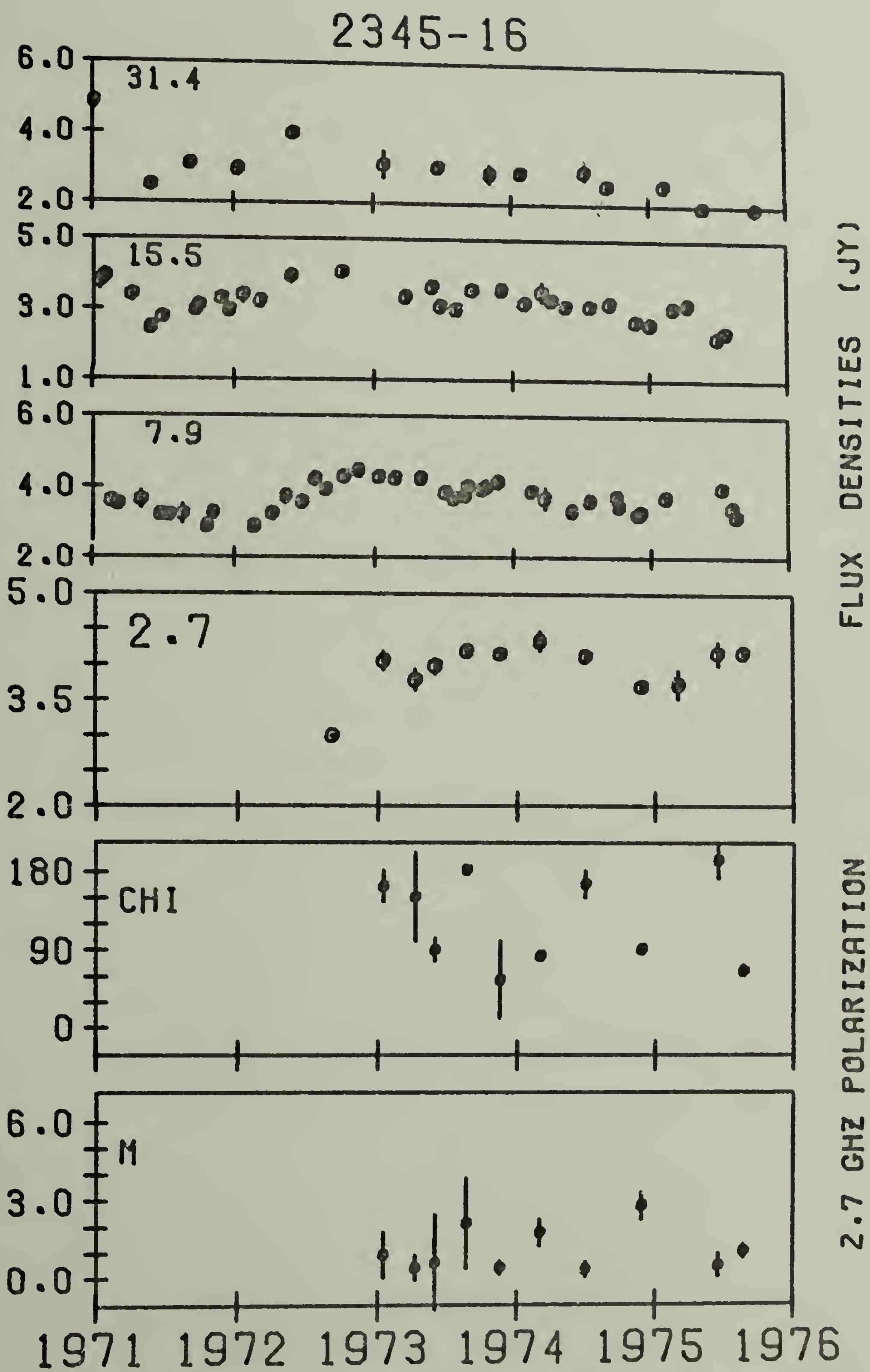
2.0
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION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7.9
5.0
3.5
2.0
2.7
180
90
0
CHI
6.0
3.0
0.0
M
1971 1972 1973 1974 1975 1976
FLUX DENSITIES (JY)
2.7 GHZ POLARIZATION

APPENDIX III

TABULAR AND GRAPHICAL PRESENTATION OF VARIABLE STANDARD SOURCE DATA

This appendix presents the numerical data and plots for each possible variable standard source. The first column gives the date of observation, the next two give the flux density and error in Janskys, the next two give the degree of polarization and error in percent, and the next two give the position angle and error in degrees. The last two columns give the number of points used in determining the flux density (NS) and polarization properties (NP). Averages for all runs for all quantities follow the individual measurements.

0256+07 (OD094.7) VARIABILITY INDEX= 2.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	.74	.01					4	
1973.04	.76	.02					3	
1973.26	.78	.02					4	
1973.40	.78	.02					4	
1973.64	.82	.02					4	
1973.88	.86	.01					5	
1974.16	.79	.02					5	
1974.50	.88	.03					2	
1974.90	.80	.01					6	
1975.16	.82	.03					2	
1975.45	.80	.03					2	
1975.63	.74	.02					6	
AVERAGES	.80	.01					12	

3C78 VARIABILITY INDEX= 2.5

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	4.99	.03					4	
1973.04	4.93	.03	1.3	.3	109.0	4.6	4	4
1973.26	5.34	.05	1.9	.4	100.2	2.8	3	3
1973.40	5.08	.06	1.6	.3	101.3	2.5	4	4
1973.64	5.06	.04	2.0	.2	96.2	1.3	5	5
1973.88	5.00	.03	1.6	.1	102.0	1.7	6	6
1974.16	5.19	.09	1.8	.2	100.3	2.1	5	5
1974.50	5.04	.06	1.9	.4	99.8	3.5	2	2
1974.90	5.17	.04	2.3	.2	99.1	1.3	6	6
1975.16	5.09	.06	2.1	.4	100.4	3.2	2	2
1975.45	5.28	.06	1.9	.5	91.7	2.7	2	2
1975.63	5.04	.03	2.0	.2	99.1	1.6	6	6
AVERAGES	5.10	.04	1.8	.1	99.6	1.4	12	11

0905+01 VARIABILITY INDEX= 2.5

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	.91	.03					2	
1973.04	.89	.02					5	
1973.26	.87	.02					6	
1973.40	.84	.03					4	
1973.63	.86	.02					4	
1973.88	.89	.01					5	
1974.16	.81	.01					7	
1974.49	.81	.02					3	
1974.90	.79	.02					6	
1975.17	.77	.04					1	
1975.45	.74	.04					1	
1975.63	.78	.02					3	
AVERAGES	.83	.02					12	

1150+49 (4C49.22) VARIABILITY INDEX= 3.4

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.55	.04					1	
1973.04	1.53	.03	4.3	.9	108.9	4.8	2	2
1973.26	1.56	.02	4.1	.7	110.1	4.2	3	3
1973.40	1.55	.03	4.3	.9	108.0	4.7	2	2
1973.64	1.55	.03	3.5	.7	122.6	10.4	2	2
1974.16	1.50	.02	3.9	.7	110.8	4.7	3	3
1974.49	1.45	.03	4.6	.9	110.8	5.0	2	2
1974.90	1.29	.04	3.6	1.3	113.2	10.9	1	1
1975.17	1.33	.04	5.3	1.4	108.6	6.3	1	1
1975.45	1.32	.04	4.[illegible]	2.3	108.0	12.5	1	1
1975.64	1.32	.04	6.6	1.6	100.2	3.7	1	1
AVERAGES	1.45	.03	4.3	.3	109.3	2.0	11	10

3C287 VARIABILITY INDEX= 2.3

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	4.60	.07					1	
1973.04	5.09	.06	4.4	.5	104.8	2.1	2	2
1973.27	4.96	.04	4.0	.3	108.9	1.9	3	3
1973.41	5.02	.06	3.8	.4	109.3	2.4	2	2
1973.63	4.82	.08	3.6	.5	111.9	4.0	1	1
1974.16	5.06	.05	4.2	.3	105.8	1.6	3	3
1974.49	4.96	.05	4.0	.4	109.2	2.4	2	2
1974.90	4.87	.05	3.8	.4	109.5	2.5	2	2
1975.17	4.90	.08	4.0	.6	107.8	3.3	1	1
1975.45	4.95	.05	3.8	.4	108.6	2.7	2	2
1975.63	5.01	.05	3.6	.3	108.6	2.1	3	3
AVERAGES	4.93	.04	3.9	.1	108.3	.7	11	10

3C395 VARIABILITY INDEX= 5.1

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	3.26	.05					4	
1973.04	3.16	.03	6.3	.5	176.0	.7	5	5
1973.27	3.22	.01	5.3	.3	175.3	.9	4	4
1973.41	3.27	.03	5.5	.3	174.1	.7	5	5
1973.63	3.23	.04	6.3	.3	173.2	.6	5	5
1973.88	3.24	.04	5.6	.6	173.5	1.3	2	2
1974.16	3.23	.05	6.1	.4	173.7	.7	4	4
1974.49	3.06	.03	6.8	.3	171.7	.6	5	5
1974.90	3.09	.03	4.8	.5	175.5	1.2	3	3
1975.45	3.10	.04	4.6	1.6	171.1	3.6	2	2
1975.63	2.70	.02	6.1	.5	170.8	1.1	4	4
AVERAGES	3.14	.05	5.7	.2	173.5	1.1	11	10

3C433 — VARIABILITY INDEX= 2.7

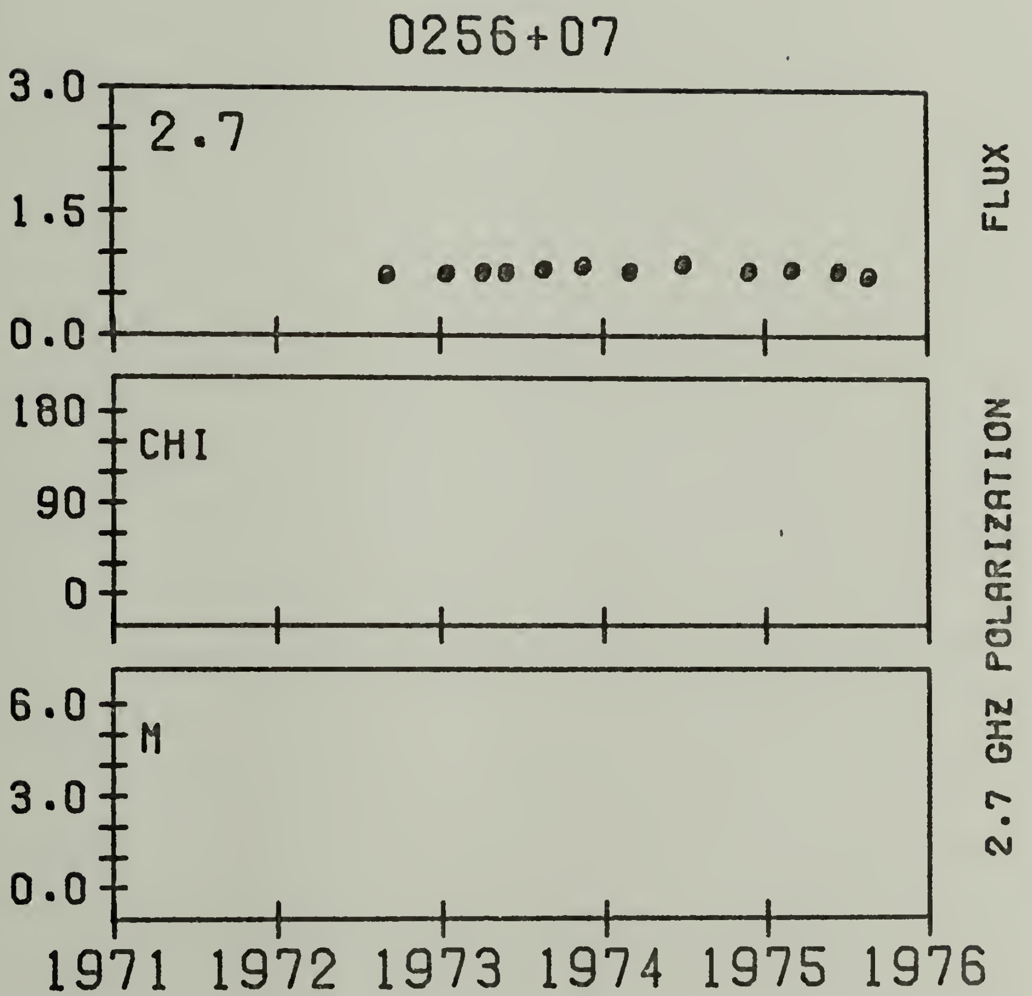
YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	6.74	.07					4	
1973.04	6.90	.09	6.5	.4	105.8	1.4	4	4
1973.26	6.79	.09	5.6	.2	110.1	1.1	4	4
1973.41	6.74	.03	5.9	.3	107.9	1.0	5	5
1973.63	6.58	.05	6.3	.2	108.2	.8	5	5
1973.88	6.62	.07	6.2	.2	105.6	.6	5	5
1974.16	6.93	.09	6.1	.2	105.7	.8	4	4
1974.49	6.90	.01	6.3	.2	106.9	.7	5	5
1974.90	7.09	.03	6.5	.2	107.3	.8	6	6
1975.17	6.81	.10	5.8	.5	109.7	2.2	1	1
1975.45	7.05	.06	6.4	.3	105.4	1.0	3	3
1975.63	6.99	.03	6.1	.1	107.3	.6	7	7
AVERAGES	6.84	.05	6.1	.1	107.2	.5	12	11

2209+08 — VARIABILITY INDEX= 3.7

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	1.44	.03					4	
1973.04	1.46	.03	3.2	.6	87.1	1.9	5	5
1973.26	1.43	.02	3.9	.9	86.9	2.6	3	3
1973.41	1.34	.01	6.4	.7	89.1	.9	5	5
1973.63	1.36	.01	3.9	.5	93.5	1.8	4	4
1973.88	1.36	.03	4.2	.4	89.6	2.2	5	5
1974.16	1.40	.01	4.1	.6	89.2	1.9	4	4
1974.50	1.26	.02	3.9	.6	90.6	1.8	4	4
1974.90	1.31	.02	4.8	.6	87.6	1.5	4	4
1975.17	1.24	.04	6.1	1.8	86.5	3.3	1	1
1975.45	1.26	.02	4.6	.6	85.7	2.4	4	4
1975.63	1.26	.02	5.0	.5	90.3	1.5	7	7
AVERAGES	1.34	.02	4.5	.3	88.7	1.9	12	11

3C161 VARIABILITY INDEX= 1.6

YEAR	FLUX	ERROR	M	ERROR	CHI	ERROR	NS	NP
1972.67	10.61	.19					2	
1973.03	10.38	.19	12.1	.5	176.4	.4	2	2
1973.26	10.72	.16	10.8	.3	177.2	.3	3	3
1973.40	11.41	.20	11.1	.8	178.4	.4	2	2
1973.63	10.91	.20	15.5	.8	177.8	.3	2	2
1973.88	10.97	.16	12.2	.3	177.6	.3	3	3
1974.16	10.64	.13	9.3	.5	175.5	.5	4	4
1974.50	11.64	.29	9.4	.8	177.5	.7	1	1
1974.90	10.94	.16	7.8	.3	175.6	.5	3	3
1975.16	10.96	.28	7.8	.6	175.3	.9	1	1
1975.63	10.99	.20	9.1	.4	176.9	.5	2	2
AVERAGES	10.97	.09	10.5	.7	177.0	2.0	11	10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M
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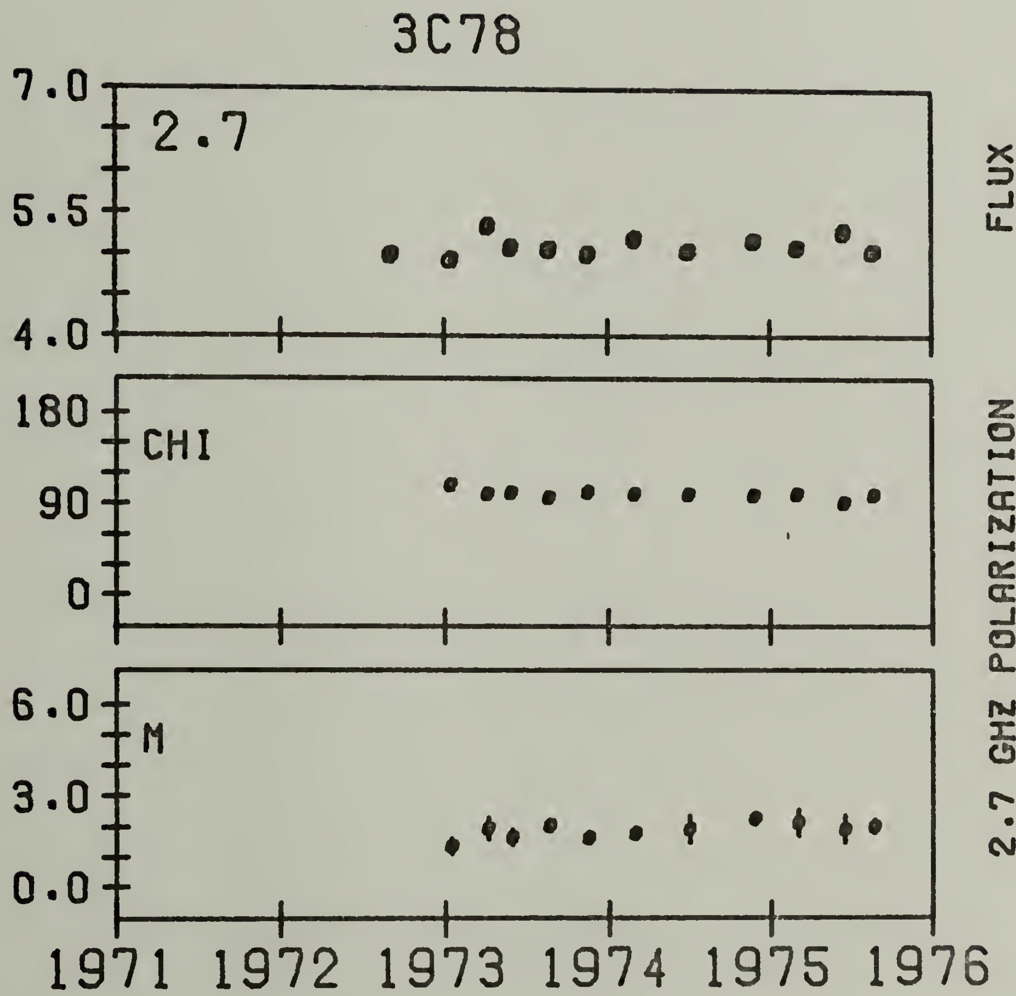
2.7 GHZ POLARIZATION
1971 1972 1973 1974 1975 1976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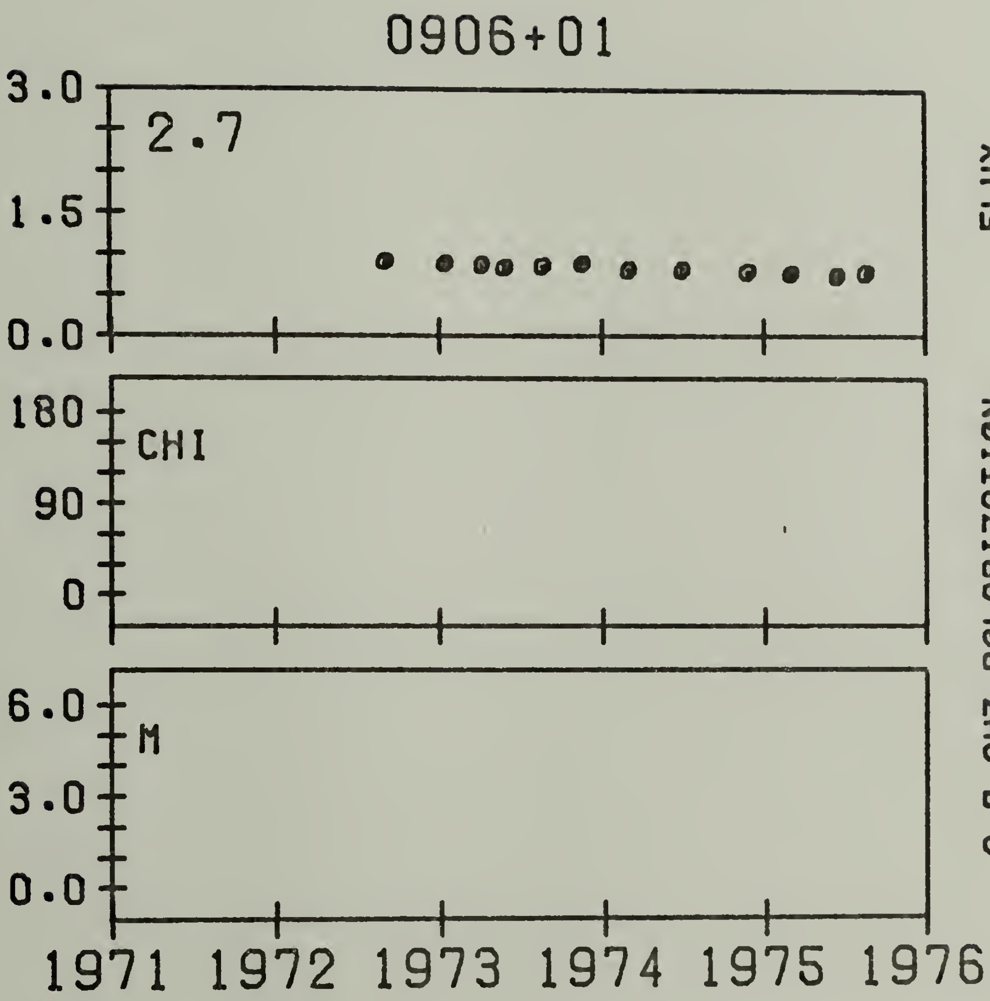
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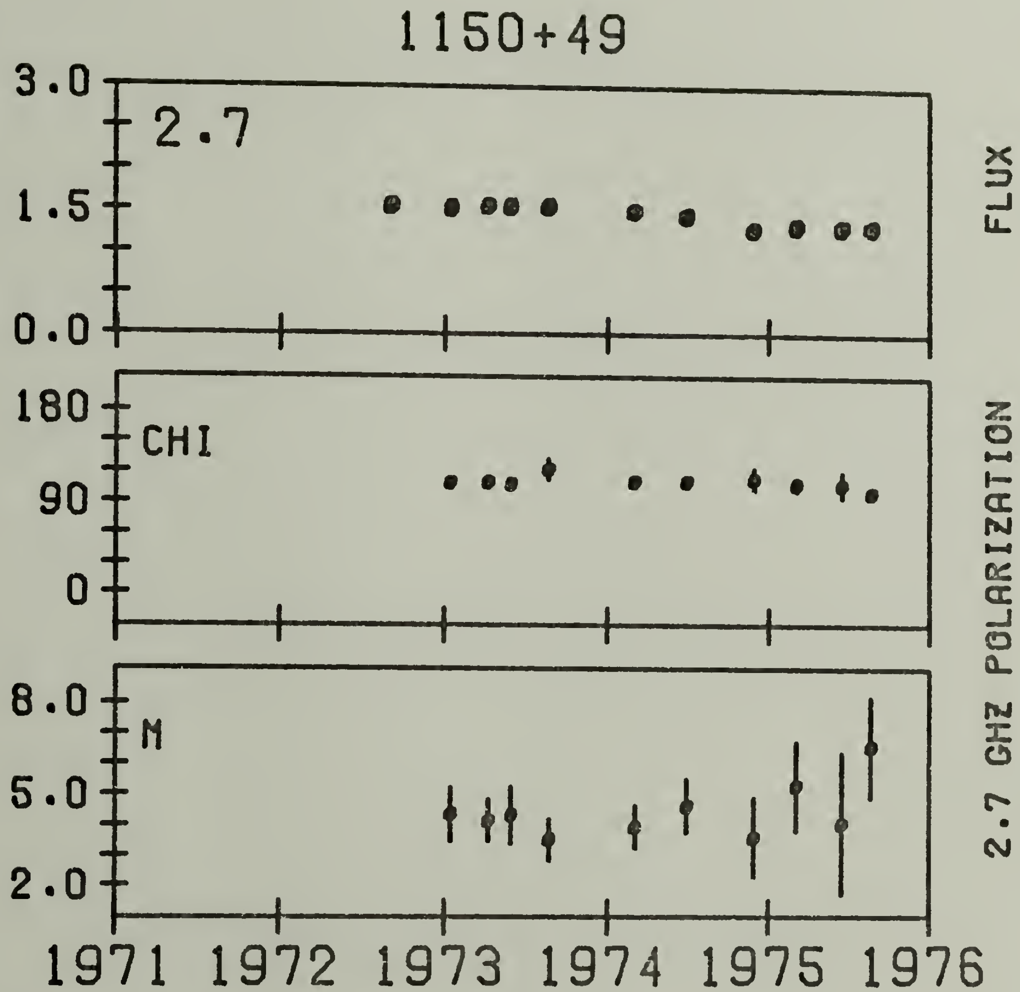
FLUX
2.7 GHZ POLARIZATION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2.7 GHZ POLARIZATION
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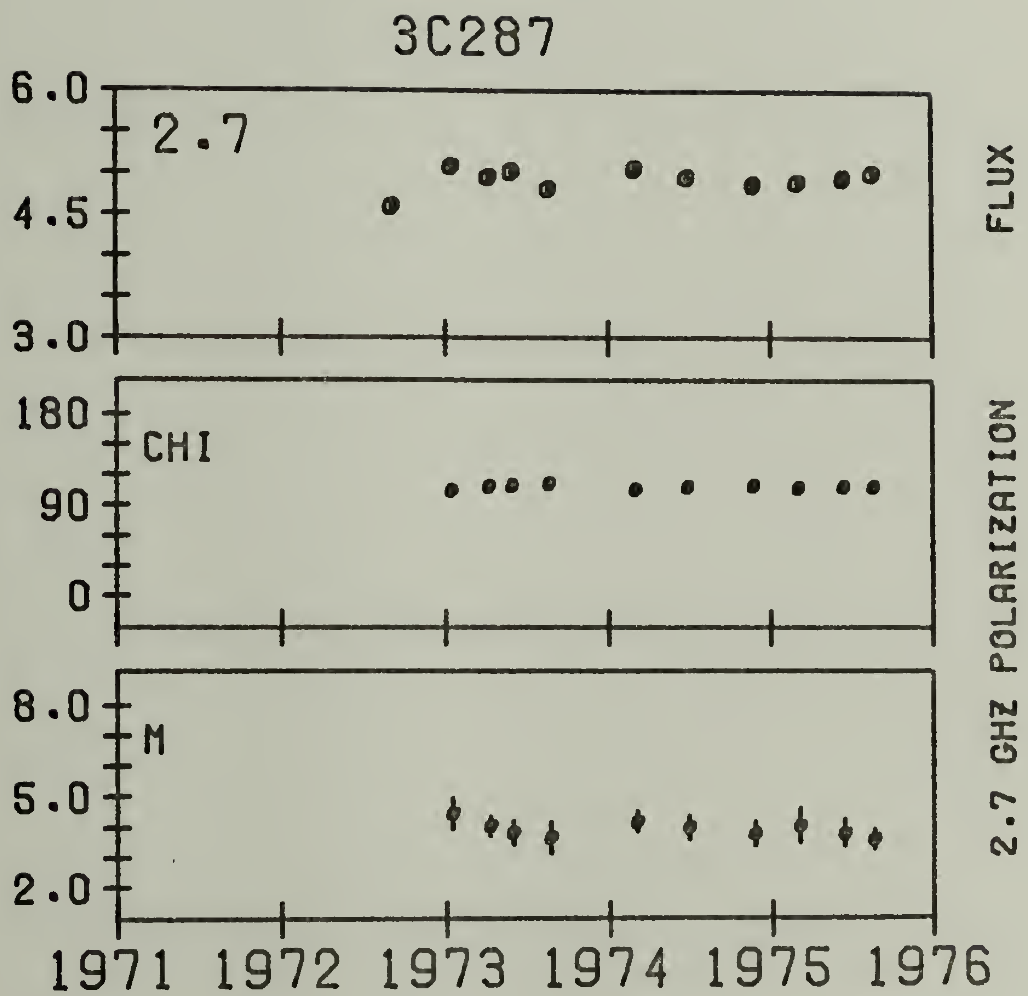
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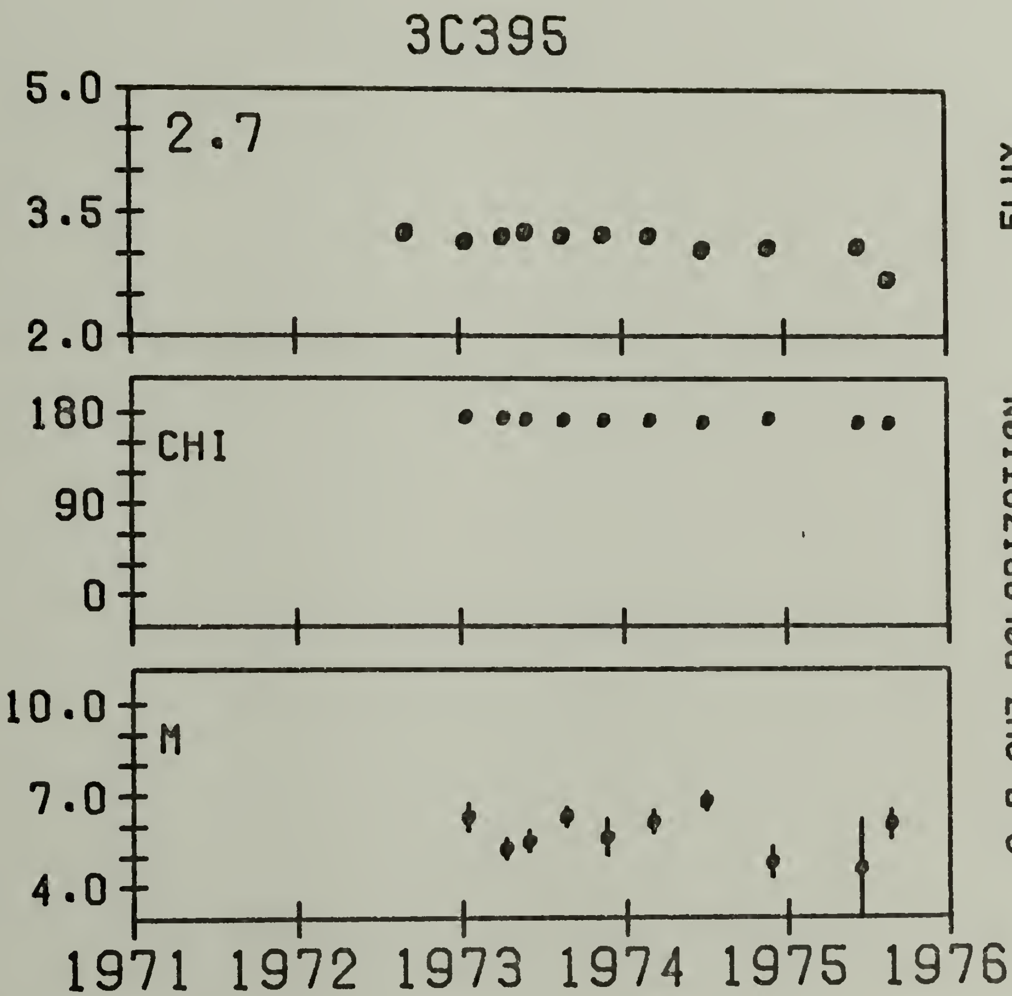
1972
1973
1974
1975
1976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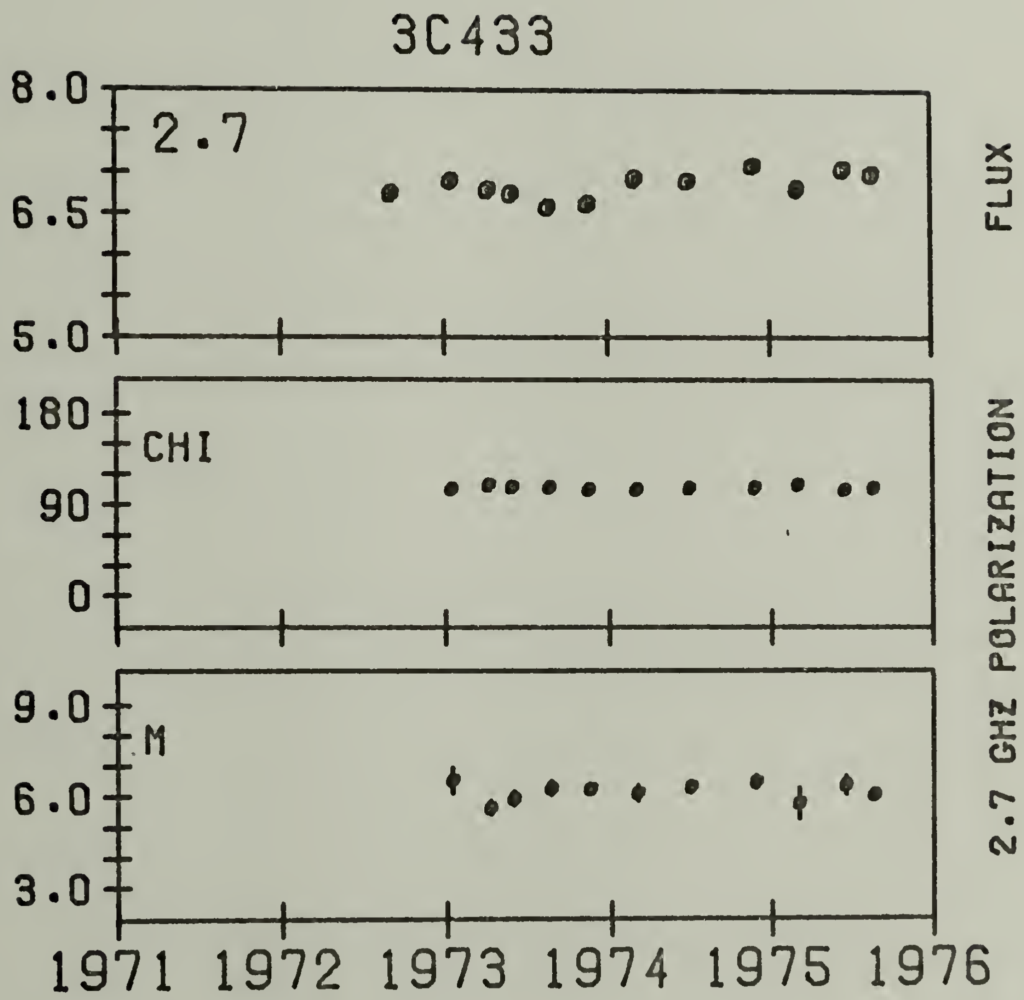
2.7 GHZ POLARIZATION
1971 1972 1973 1974 1975 1976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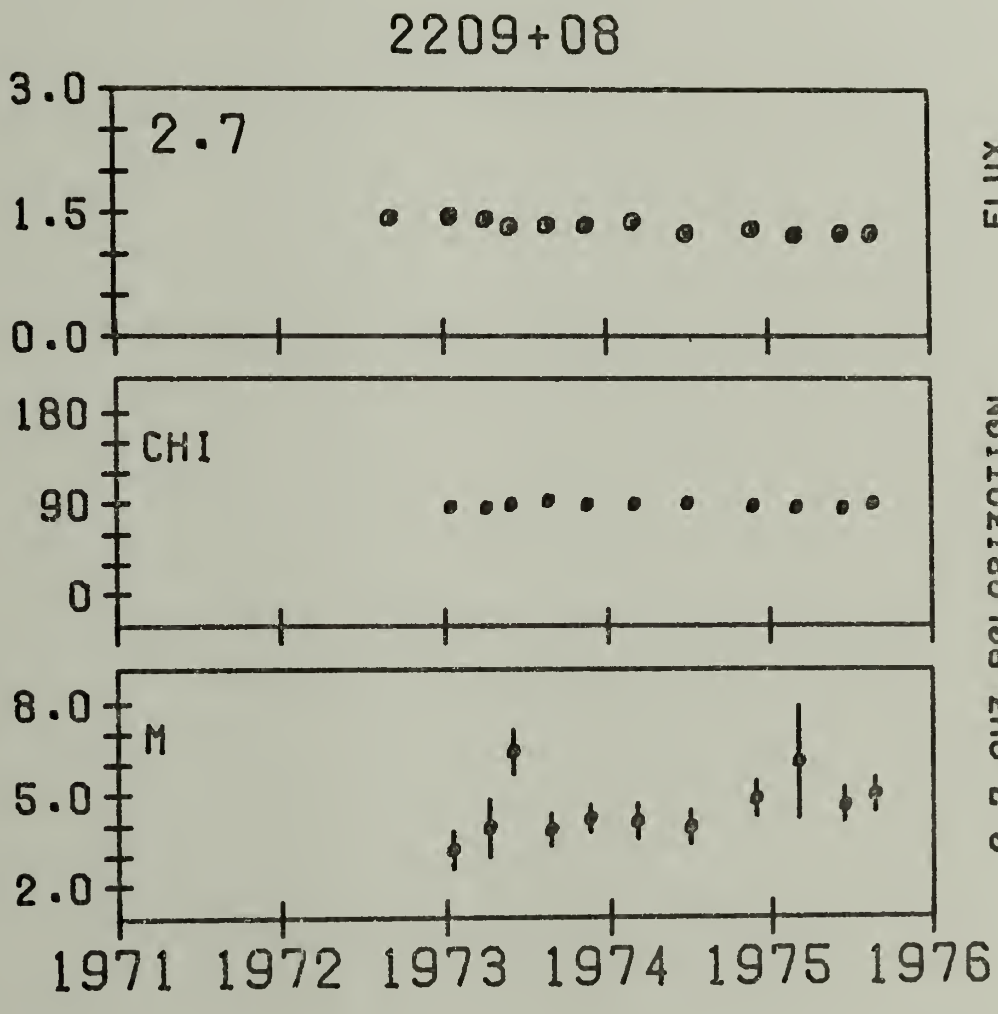
2.7 GHZ POLARIZATION
1971 1972 1973 1974 1975 1976



2209+08
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FLUX
CHI
M
2.7 GHZ POLARIZATION
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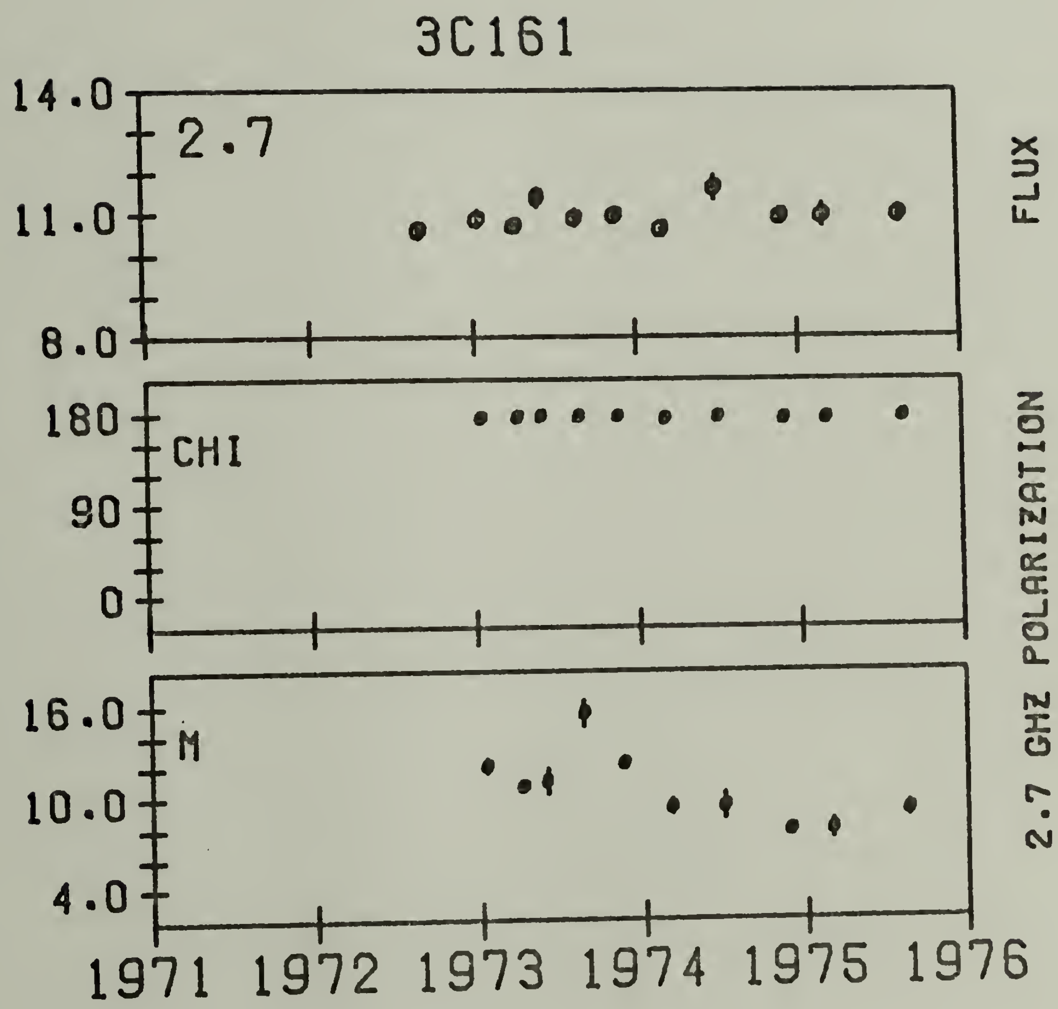
1973
1974
1975
1976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CHI
90
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2.7 GHZ POLARIZATION
1971 1972 1973 1974 1975 1976